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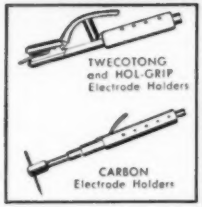

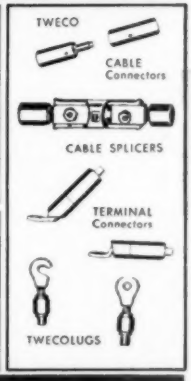

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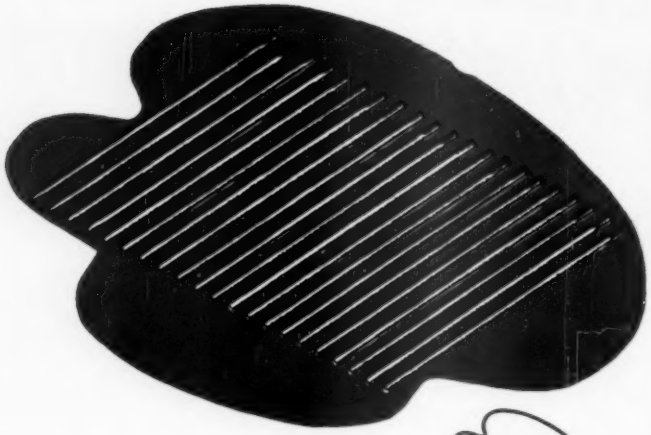

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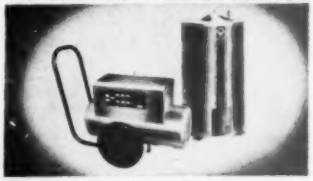

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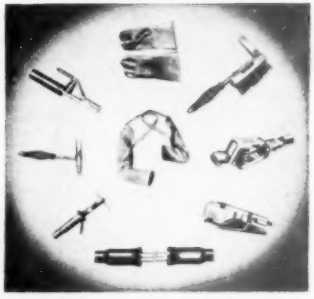

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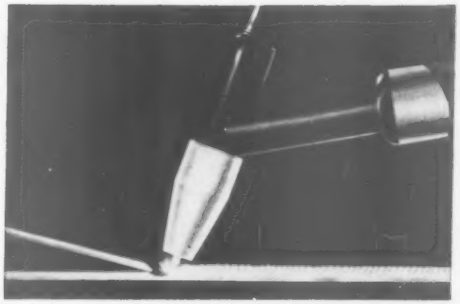

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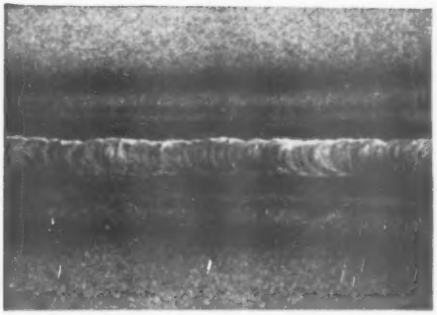

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The WELDING JOURNAL

volume 28 December 1949 number 12

Fabrication of Large Alloy-Steel Shovel Buckets

Welding of high-yield strength armor-type alloy steels for shovel buckets is a relatively new development. Fabrication problems are briefly discussed and illustrated

by E. R. McClung

DURING the past few years the use of alloy steels for dipper-type shovel bucket construction has advanced to a point at which the application is proved industrially practicable as well as being of profitable advantage to the user of large shovels. Great credit is due to those power shovel manufacturers who pioneered in this field and to those users of such equipment who made the advances possible by their willingness to explore relatively uncharted fields.

This work consists chiefly of the application to such operations of heat-treated alloy steels having relatively high-yield strengths (80,000 psi. min.), the weldability of these particular types of steel having been outgrowths of various research and development projects undertaken in connection with prewar and wartime defense activity. These steels are in general of the armor type having high-impact strength and resistance to shock, and are therefore admirably suited to the purpose at hand, provided they can be satisfactorily fabricated into a suitable structure.

Perhaps the most generally used steel for this purpose has been a relatively low-carbon (0.15–0.20%) steel alloyed with about 1.5% manganese and 0.40–0.50% molybdenum known as manganese-molybdenum steel and sometimes affectionately known, in the light of current scrap conditions and open-hearth practice, as "garbage" steel. This steel when normalized, reheated and drawn at 1150° F. will give yield strengths of at least 80,000 psi. in light or medium gages although in heavy gages (from 2 in. up) this level may not quite be attained under all conditions.

Also, there have been developed a number of high-manganese alloy steels having high-yield strengths and tensile strengths in excess of 100,000 psi. when hot rolled and normalized. These steels have high ductility, are austenitic and have extreme cold-work hardening characteristics which make them suitable for abrasion-resisting applications.

A particularly attractive steel of this type, containing about 0.35% carbon, 13% manganese, 3.25% nickel, 4.25% chromium and 0.45–0.50% molybdenum, is available commercially for such applications and has as an important advantage the fact that it is readily weldable, using austenitic electrodes.

The time comes in all new successful applications when it appears desirable to look for means of smoothing out rough spots and generally improving the product. The specific requirement in this case was to improve serviceability and thus cut "down time" resulting from bucket failures which not only were expensive to repair in the field but completely immobilized a terrific investment in equipment and manpower whenever they occurred. With this requirement in mind, a program was undertaken to develop a structural design which could be fabricated of high-strength steel and thus produce a bucket structure having minimum stress concentration and maximum shock- and impact-resistance characteristics.

The program as undertaken fell into three categories, as follows: (1) Design, (2) Test and Development, and (3) Fabrication. Each will be considered but main emphasis will be placed upon the fabrication aspects as they relate to the over-all problem.

DESIGN

It is not proposed to discuss detailed design features of shovel buckets. It is intended to point out that design thinking involved the rejection of complicated structure comprising large numbers of structural members with multitudinous points of intersection and the

E. R. McClung is Superintendent, Lukenweld Div., Lukens Steel Co., Coatesville, Pa.

Presented at the Thirtieth Annual Meeting, A.W.S., Cleveland, Ohio, week of Oct. 17, 1949.

acceptance of a simple basic structure of suitable strength having a minimum number of points of stress concentration. Consequently, the designs were developed with emphasis on the inherent stability of the structure without detracting from the functional requirements, following the concept of placing steel in the right proportions where its physical properties could be most effectively utilized.

To achieve this result, in the case of the buckets themselves, it appeared desirable to design on the basis of using fairly heavy main frame members to develop the requisite strength and still provide for smooth, even stress distribution throughout. Putting it in another way, designing in lighter scantlings involved miscellaneous additional bracing and reinforcing material to an extent which jeopardized the concept of minimum stress concentration. With this in mind, what in effect was a one-piece basic frame was conceived of manganese-molybdenum steel, with the yield strength being scaled down to allow for the somewhat reduced strength obtainable in heavy plates, and using austenitic steel of the high-manganese type at points of major wear.

In the course of this design program, extensive use was made of wooden models. Such models were of considerable assistance in the initial design stages and in coordinating design problems with those of fabrication. A typical wooden model is illustrated in Fig. 1.

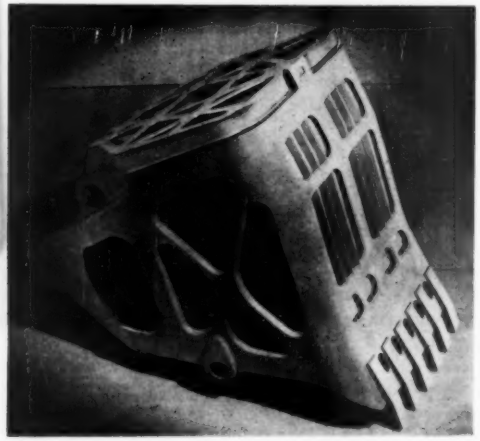

Fig. 1 Preliminary, wood model of 50-cu. yd. bucket

In handling the design of other component sections of the buckets the same general trend of thinking was followed. Full use was made of formed and cut sections developed to provide the best possible conditions of stress distribution and the most suitable contours from a functional standpoint. Selection of material to be used depended upon the service to which a particular part would be put and, with this in mind, manganese-molybdenum steel was used exclusively for fabricated dipper sticks subject to heavy fatigue loads and shock, and austenitic steel was used for doors and bails subject to direct impact and abrasion.

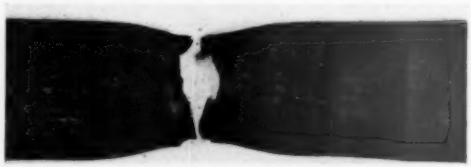

Fig. 2 Full section tension specimen in 3-in. thick manganese-molybdenum steel plate

TEST AND DEVELOPMENT

Considerable preliminary work was required in order to determine the most satisfactory welding conditions for butt welding the heavy main frame members of manganese-molybdenum steel and for the fillet welded connections of the high-manganese abrasion-resisting steel to the framing members.

The first step in this development lay in the selection of suitable electrodes for performing the welding:

(*a*) The available types of so-called "lime-ferritic" electrodes were investigated for the first application. Initially there was some doubt as to the desirability of using this type of electrode on fully heat-treated steel of heavy thicknesses but early study pointed definitely toward the impracticability of obtaining suitable yield strengths from full-section specimens in which the welds were deposited with austenitic electrodes. Since it was essential to obtain the highest practicable joint efficiency consistent with the requirements, major thought was transferred to the E10016 American Welding Society classification of electrodes.

Using electrodes of this type, it was possible to obtain welds in 3-in. thick material, which, in full section specimens, gave the following properties:

Yield strength, psi.	75,000– 80,000
Tensile strength, psi.	96,000–102,000
Elongation in 2 in.	20–32%

Fig. 3 Side-bend specimen of weld in 3-in. thick manganese-molybdenum steel plate bent to 180° without fracture

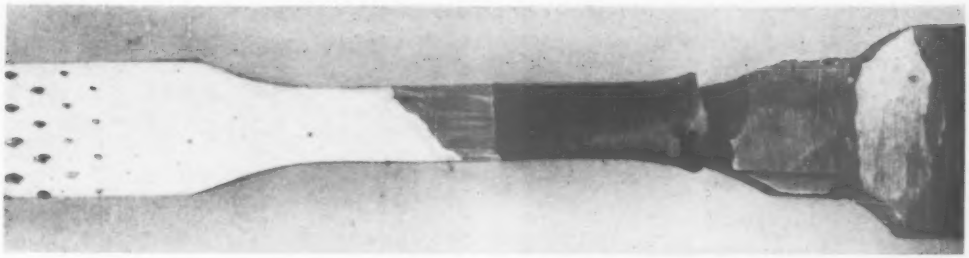

Fig. 4 Reduced section-tension specimen of 3-in. thick manganese-molybdenum plate to austenitic plate

Side-bend specimens of these welds consistently bent 180° without fracture when tested in the U. S. Navy Guided Bend Test Jig. Figures 2 and 3 will give some indication of the physical characteristics of these full section specimens.

(*b*) In view of the austenitic nature of the abrasion-resisting portions of the shovel buckets, it was necessary to use an austenitic weld metal at all connections involving this material. Fully satisfactory properties were obtained by the use of 29% chromium–9% nickel electrodes and these were selected on that basis plus their relative economy as compared to other suitable types of austenitic electrodes. Reduced section tension test and guided-jig bend-test specimens made under these conditions are shown in Figs. 4 and 5.

The second step lay in the selection of satisfactory joints to permit full penetration welds wherever possible. These selections were resolved as follows:

(*a*) Main butt joints in heavy thicknesses were designed with a special double-vee butt joint having a center backing strip, removable in back gouging.

(*b*) Lighter thicknesses in austenitic and in manganese-molybdenum steel were designed using single-vee butt joints, as were all butted intersections of manganese-molybdenum steel with the austenitic steel, although in the latter case it was necessary to resort to use of a backing strip in some instances in which it was not possible to otherwise obtain a full penetration weld.

(*c*) Double fillet-welded tee joints were used for the attachments of stiffeners and of main frame members to austenitic lining structure.

The third step lay in establishing an acceptable welding procedure for performing the work. Much of welding procedure, as such, is properly a part of fabrication, yet certain elements of it needed to receive full consideration in the development stage.

(*a*) For all connections involving the use of E10016 electrodes it was found essential to preheat to 350° F. to prevent cracking. Preheat ranges at higher temperature levels were explored but it was found that such levels offered no appreciable advantage consistent with the greater difficulties of fabrication resulting therefrom. Maintenance of a corresponding interpass temperature and the principle of completing any given joint before permitting reduction below this level were established as standard practice for this type of welding.

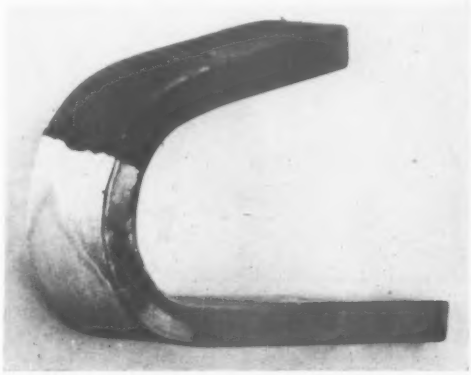

Fig. 5 Side-bend specimen of weld of manganese-molybdenum to austenitic plate

At such connections the practice of depositing the last bead of any given joint on previously deposited weld metal rather than in contact with parent metal was established as part of basic procedure.

(*b*) For most connections involving austenitic steel, weld metal tests led to the conclusion that no basic pre-

Fig. 6 Die-formed main side plate of 3-in. thick manganese-molybdenum steel for 50-cu. yd. bucket

Fig. 7 Basic frame assembly of fifty-cu. yd. bucket

heat was required because of the inherent ductility of the austenitic weld deposits. It was desirable to remove chill from the metal, however, and a preheat minimum of 100° F. was established for all such connections. At butt joints to manganese-molybdenum steel, the higher preheat level was concluded to be desirable.

(*c*) Magnaflux inspection of all backside preparations in manganese-molybdenum steel was considered essential to insure freedom from cracking, as was magnafluxing of every third or fourth layer of weld deposit in such steel.

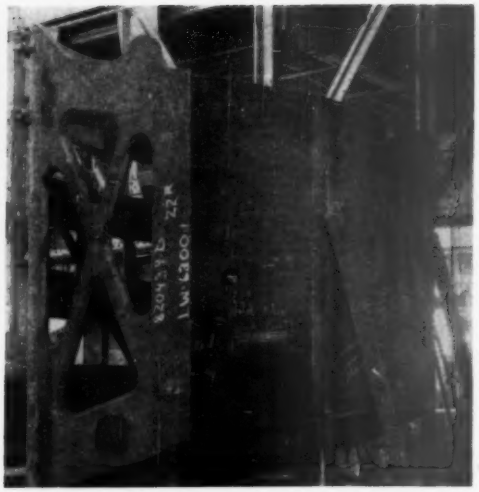

Fig. 8 Forming of rear austenitic steel-liner plate for twelve-cu. yd. bucket

(*d*) In view of the difference in welding characteristics of lime-ferritic electrodes from those ordinarily used in job-shop operation, it was necessary to establish special operating conditions and to train operators specially to maintain proper arc length and technique when making welds with these electrodes. Such measures were required only to a very limited extent when using austenitic electrodes on this class of work.

(*e*) No postheat requirements whatsoever were found necessary as a result of performing stress-relieving operations on a number of specimens for subsequent test. As far as completed assemblies were concerned, postheat treatment was undesirable because of differences between expansion coefficients of the materials involved.

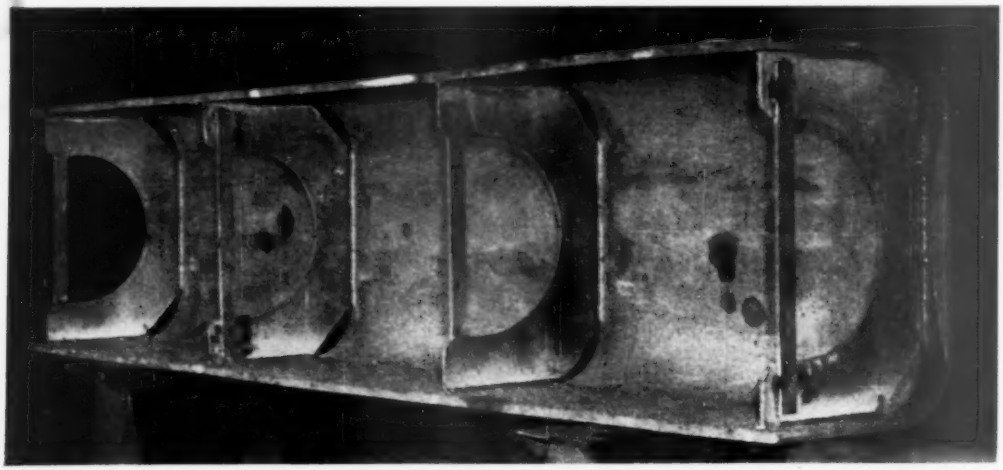

Fig. 9 A formed channel section of manganese-molybdenum steel for dipper stick of fifty-cu. yd. bucket

Fig. 10 Arrangement of strip heaters for preheating main side plates for fifty-cu. yd. bucket

Fig. 11 Welding of door for forty-cu. yd. bucket on universal positioner

Fig. 12 Failure of butt weld in top flange of bail of twelve-cu. yd. bucket

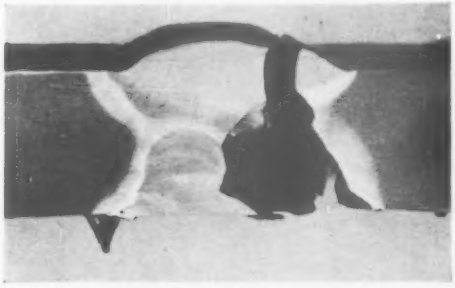

Fig. 13 Cross section of fracture showing separation along interface of ferritic weld deposit

Fig. 14 Powder cutting of 1-in. thick austenitic steel plate for door of fifty-cu. yd. bucket

Fig. 15 Flame-cut sections of 7-in. thick steel plate for tooth bases for fifty-cu. yd. bucket

Fig. 16 Flame-cut manganese-molybdenum steel yoke sections for bail of fifty-cu. yd. bucket

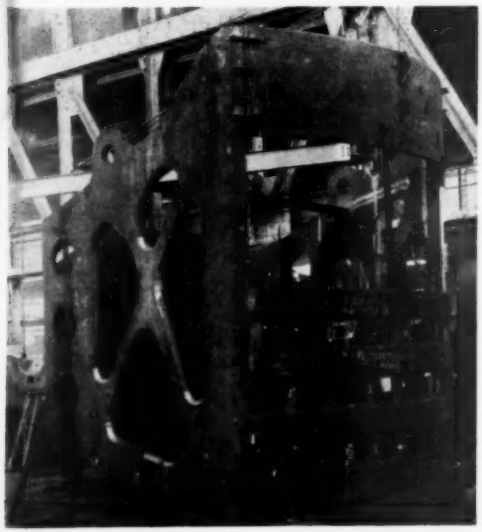

Fig. 17 Fifty-cubic yard bucket frame showing early stages of assembly of austenitic steel abrasion resistant forward structure

FABRICATION

In fabricating shovel buckets and appurtenant parts using the steels mentioned, it was apparent in advance that many of the usual methods of fabrication would have to be modified to suit the characteristics of the materials being worked. Many standard methods were, of course, applicable in some cases, but adaptation of new techniques and of the most up-to-date methods were required in several instances.

Particular emphasis in fabrication must be placed upon the gas cutting problems. The quench-hardening characteristics of manganese-molybdenum steel are such that unless special heat treatment is performed, edge cracking of a deleterious nature will result. Furthur, the rough-cut edges are impossible to machine.

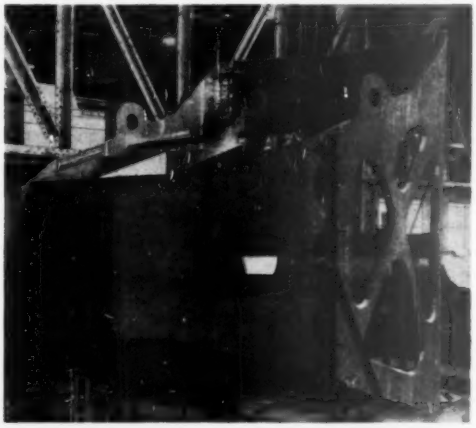

Fig. 18 Rear view of main frame of fifty-cu. yd. bucket showing tapers in way of dipper stick connections

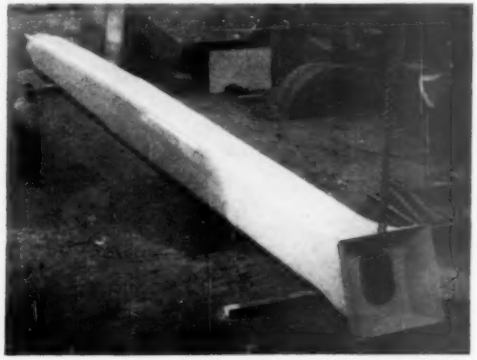

Fig. 19 Completed dipper stick for fifty-cu. yd. bucket

Fig. 20 Connection of bucket teeth to tooth bases for twelve-cu. yd. bucket

Studies of preheat and postheat treatments had led to the conclusion that the most consistent results were obtainable by resorting to furnace treatment at 1000° F., with air cooling immediately after completion of cutting the steel at a preheat temperature of at least 350° F. This was established as standard practice for the material. In the case of the high-manganese austenitic steel, all cutting was done using the powder cutting method as developed in recent years, no preheat or postheat being required. During assembly it was found that, for assembly purposes only, a surprisingly satisfactory cut could be made manually, using a highly oxidizing flame and a so-called "melt-cut" technique, but such practice is hardly recommended for preliminary fabrication work either from an economy or a quality standpoint.

Since the design concept, as previously stated, was based upon the most effective utilization of the material properties with minimum conditions of stress concentration, preforming of material was resorted to whenever conditions so dictated. Figure 6 illustrates the front half of the main side plate of a 50-yd. bucket, this piece being die formed of 3-in. manganese-molybdenum steel on a 1000-ton press. Figure 7 shows this plate after subassembly with the rear side plate and also illustrates the use of the formed top and bottom main front-frame plates, also of 3-in. manganese-molybdenum steel. Immediately above the bottom front-frame plate is a 12-in. channel formed of 1-in. austenitic steel of the same curvature as the frame plates, this being one of several such pieces comprising the main front abrasion resisting structure. Figure 8 shows a 1-in. austenitic steel plate bent to form the rear liner of a 12-cu. yd. bucket and also illustrates the forming along the front edge of the single-plate main side-frame member. Figure 9 illustrates one of the channel sections which were formed of $^3/_4$- and 1-in. manganese-molybdenum steel and which, with internal ribbing structure, were fabricated into the dipper handle or stick for a 50-yd. bucket. Forming of these members represented a special problem in itself, due to the high yield strength and extreme "spring-back" characteristics of the material. It was found necessary to place the internal framing in position and weld it to the web of the channel sections, then force the flange sections

Fig. 21 Completed twelve-cu. yd. bucket in fully machined condition with door and bail plus control gear and snubbers

Fig. 22 Fifty-cubic yard bucket ready for shipment with 2½-ton truck therein to give conception of size

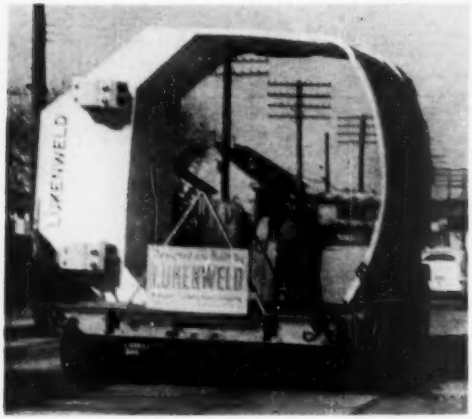

Fig. 23 Fifty-cubic yard bucket enroute to Adena, Ohio

into contact with the ribs and weld while in position under a press.

As a result of the program previously outlined, relatively few difficulties were encountered in welding bucket structures. The practice of painting joints in color and providing welding operators with a color legend was established and satisfactorily prevented confusion in use of electrodes and preheat requirements. Preheat was maintained by use of electrical strip heaters as shown in Fig. 10, although when welding was actually in progress the strips were covered with insulation to prevent loss of heat and injury to operators. At all joints in heavier gages of material, welding progressed on a 24-hr. basis in order to eliminate any possibility of cracks resulting from successive cooling and heating. The standard magnaflux technique was followed throughout in an effort to keep maximum control over cooling and shrinkage cracks.

Throughout welding operations the practice of welding first from the least accessible side was followed. Because of the hardening characteristics of the steels

Fig. 24 Setup for preheating and welding dipper stick to fifty-cu. yd. bucket at Hanna Coal Division Shop

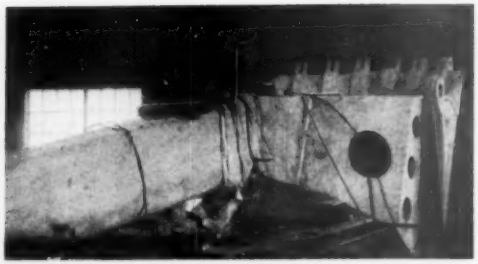

Fig. 25 Dipper stick welded to fifty-cu. yd. bucket in Hanna Coal Division Shop

and electrodes used, back gouging presented some problems of its own and necessitated this consideration. In manganese-molybdenum steel, back gouging was accomplished by flame deseaming, followed by grinding as required. At joints welded with austenitic electrodes, back gouging was accomplished by rough chipping, followed by grinding to clean metal.

Tooth bases were welded to the manganese-molybdenum top front plate with E10016 electrodes without difficulty, but welding the teeth themselves proved to be something perplexing. These teeth consisted of a cast austenitic steel (similar to the austenitic plate in analysis) welded to a manganese-molybdenum steel body. The latter would not weld satisfactorily when cold and welds to the former spalled out at the fusion zone with any preheat at all. After some anguish the problem was solved by "buttering" the casting with 29% chromium–9% nickel weld metal when completely cold and then welding the "buttered" surface to the tooth body with similar electrodes under suitable preheat conditions.

Throughout welding operations work was positioned for downhand welding whenever possible. This is especially desirable with lime-ferritic electrodes to control porosity to the greatest possible extent. Figure

Fig. 26 Twelve-cubic yard bucket mounted on dipper stick in field

Fig. 27 Twelve-cubic yard bucket set up for operation

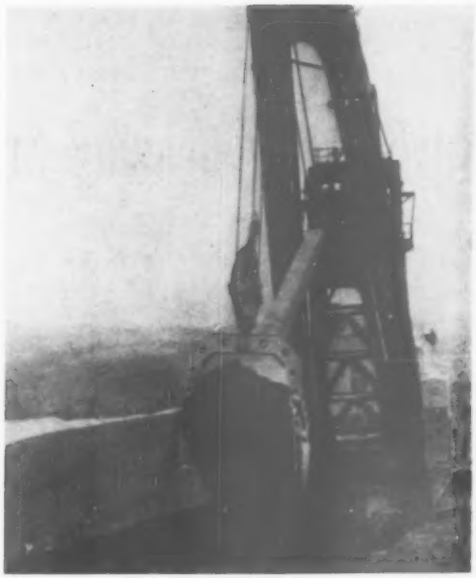

Fig. 28 Fifty-cubic yard bucket in operation digging at Adena, Ohio

11 illustrates a door for a 40-yd. bucket being welded on a universal positioner to facilitate welding in this fashion.

From a fabrication standpoint, it has become apparent that with proper preparation, instruction and control, welding of these steels does not present any insurmountable problems. Control measures may fail on occasion, with possible serious consequences, but constant vigilance is the price of prevention and is a price that must be paid when working these materials. If vigilance relaxes an operator may inadvertently use a ferritic electrode on austenitic steel, with results shown in Figs. 12 and 13. Or a direct-current power failure may shut off the strip heaters and transverse cracks suddenly begin to appear due to adequate preheat temperatures not being maintained. The prevailing feeling has been that the relative freedom from difficulty in shop welding operations was a reward paid for extremely thorough design and development work and for careful planning and controlling of the shop operations themselves.

Figures 14 to 28, inclusive, illustrate some of the steps in assembling and welding various buckets and show completed units under different conditions. These units range from relatively small buckets of 7-cu. yd. capacity up to the 50-cu. yd. bucket, believed to be the largest of its type in the world. This bucket is shown in operation in Fig. 28.

Field experience to date with these buckets has been gratifying. Obviously no point of perfection has been reached, but it is felt that this recent work represents a major achievement in the field of shovel equipment and by further study and effort, with the cooperation of field operators, more progress leading toward improved serviceability and functioning will result.

In concluding, the author would like to express his appreciation to the Hanna Coal Division for permission to present certain information and illustrations, to the Development Engineering, Research and Advertising Departments of Lukens Steel Co., for their assistance and to Mr. John L. Lang for his invaluable help in developing, establishing and controlling welding procedure during the fabrication of the buckets under discussion.

Silver Alloy Brazing Stainless Steel

In brazing stainless steel it is necessary to have good fit, clean metal, proper fluxing, adequate jigging or support, proper heating during brazing and final cleaning

by C. H. Chatfield and A. W. Swift

THE development of the silver-brazing alloys flowing at temperatures below 1200° F., which are now so widely used for joining a great variety of both ferrous and nonferrous metal objects, may be attributed in a large degree to the search some years ago for a suitable method of brazing various alloys without excessive annealing or change in properties. It was in the course of this investigation that these high-strength, low flow point, alloys were discovered. Also, prior to this time, the only commonly used fluxes for silver brazing consisted of borax and boric acid mixtures, or borax alone. The need for a flux capable of dissolving the refractory oxides formed on stainless steel during heating led directly to the development of the efficient low melting fluxes of the present day.

Numerous articles describing the fundamental procedures to be followed in the general use of the silver-brazing alloys have been published in the technical literature. In brief, it might be stated that in applying silver-brazing alloys to stainless steel, extra emphasis should be placed on each of the six fundamental steps of silver brazing. These will be quickly reviewed here.

1. Good design incorporating a good fit with a clearance of from 0.0015 to 0.005 between the surfaces to be brazed.

2. Clean metal, which in the case of stainless means abrasively cleaning, plus degreasing, just prior to the fluxing operation.

3. Proper fluxing, which means a thick continuous coat of the paste flux over both surfaces to be brazed.

4. Assembling and supporting the work to be brazed is important in order to maintain alignment during the heating operation.

5. The heating and applying of the brazing alloy require special care on stainless to avoid localized overheating, as it is important to have both members up at the brazing temperature at the same time.

6. The final cleaning, after brazing, is simple, if sufficient flux has been used, as it is then readily removed by application of hot water or steam. Trouble with flux removal is generally caused by insufficient flux, overheating or a combination of both.

A more detailed description of the cleaning, fluxing, jigging and heating of brazed joints is not necessary here, as this has already been discussed in previous papers.[6-8] Rather it is the purpose of this paper to discuss and to attempt to clarify some of the problems specifically encountered in the silver brazing of the various stainless-steel alloys.

CARBIDE PRECIPITATION

The corrosion resistance of stainless steel is presumably the result of the formation of a thin film of oxide on the surface. Once formed, this film prevents further corrosion under most atmospheric conditions and is also resistant to attack by many chemicals. When austenitic stainless steels (including 18-8) are heated to temperatures ranging from 900 to 1400° F. complete chromium carbides precipitate, largely along the grain boundaries. It is generally an accepted belief that this precipitation decreased the chromium content available at the grain boundaries below that necessary to maintain the corrosion resistance of the steel. As a result, intergranular corrosion and embrittlement may occur.

Fortunately, a complete precipitation of the carbide is relatively slow and is a function of both time, temperature and other chemical compositions of the alloy. Therefore, although no high-strength brazing alloy has been developed which can be used below the critical temperature range for carbide precipitation, yet by the use of low-temperature silver-brazing alloys, the brazing time can be kept so short that the amount of carbide precipitation is negligible. Thus the corrosion resistance is not lowered below the requirements for the large majority of uses, providing the carbon content is low. Refer to Figs. 1 to 3, inclusive, showing micrographs of pieces of stainless steel tubing (0.10 carbon). Figure 1 is as-received. Figure 2 is brazed with a low-flow point, silver-brazing alloy* in about 20 sec. Figure

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Presented at the Thirtieth Annual Meeting, A.W.S., Cleveland, Ohio, week of Oct. 17, 1949.

* Proprietary alloy, Easy-Flo No. 45 (45 Ag, 15 Cu, 16 Zn, 24 Cd).

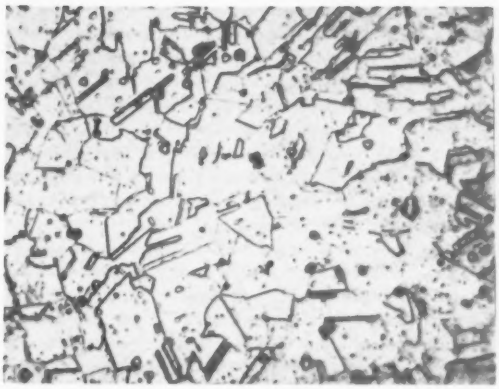

Fig. 1 Micrograph of stainless-steel tube section (0.10 carbon) as-received

Electrolytically etched with 10% chromic acid, plus potassium dichromate for the silver-brazing alloys. 500 ×

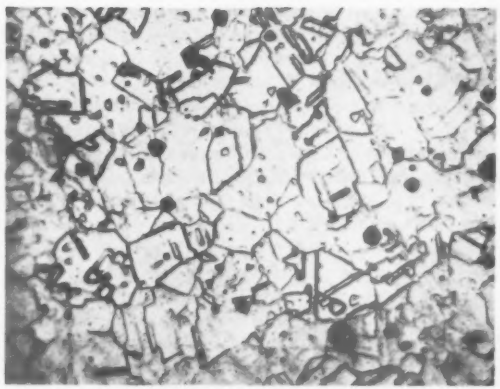

Fig. 2 Micrograph showing the quick 20-sec. silver braze on the stainless section

Etchant, same as Fig. 1. 500 ×

3 was brazed with a longer heating period, approximately 2 min. Note the carbide precipitation.

The higher the carbon content of the steel the greater the amount of carbide precipitation that will be obtained in a given heating cycle. Under those conditions where precipitated carbides will render stainless less resistant to corrosion, it is preferable to use a stainless steel having a low-carbon content. The effect of carbide precipitation can be avoided also by the use of stabilized steels. In these steels an element is added which preferentially forms carbides. Carbon will form more stable carbides with titanium or columbium, for instance, and therefore less carbon will be available to combine with chromium, thus leaving the chromium free to perform its normal function of producing a protective film.

For a detailed investigation of the effects of temperatures of from 840 to 1200° F. on stainless steel for varying lengths of time, see the technical paper by Samuel J. Rosenberg and John H. Darr.[1]

STRESS CRACKING

The most commonly used silver-brazing alloys for stainless steel contain relatively high percentages of zinc or cadmium, or a combination of both zinc and cadmium. Fire-cracking and stress-cracking have been considered a troublesome source of difficulty in silver brazing stainless and there has been a widely disseminated belief among fabricators of stainless steel that this is the result of selective intergranular diffusion of zinc into the steel from the silver-brazing alloy. This problem has been investigated and the following conclusions made.

There are two types of cracking. The first type is the result of stresses left in the metal from cold working. This stress, plus the additional stresses which may be introduced by uneven or too rapid heating, causes the steel to fire-crack. The cracking may occur at a temperature below the melting point of the brazing alloy and bears no relation to the composition of the

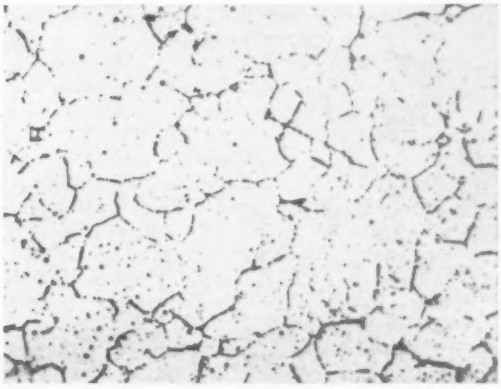

Fig. 3 A 2-min. silver braze, micrograph shows carbide precipitation

Etchant, same as Fig. 1. 500 ×

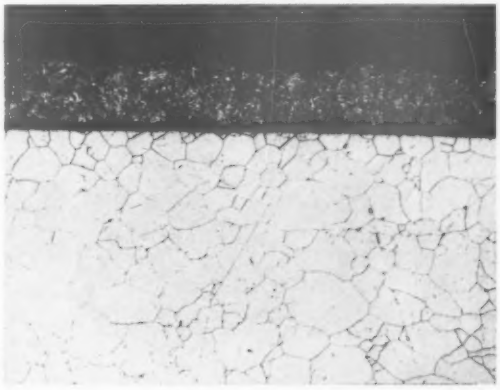

Fig. 4 Unstressed 18–8 stainless steel soaked in molten silver-brazing alloy for 20-min. at 1300° F.

There are no signs of cracking. 100 ×

brazing alloy. When the brazing alloy does melt, however, it may flow into these cracks and examination of the joint may give the impression that intergranular diffusion was the cause of the cracking.

The second type of cracking is effected by the molten-brazing alloy. As in the first type, either internally or externally applied stress must be present for cracking to occur. It differs from the first type in that the cracking does not occur until after the brazing alloy flows. The wetting of the surface of the steel weakens the surface layer, disrupts the equilibrium of the stresses present, and cracks develop rapidly along the grain boundaries. The action is similar to the familiar cracking of stressed brass in ammoniacal atmospheres or in the mercurous nitrate test. Many metals are subject to cracking under stress while in contact with a molten metal.

Microscopic examination of cracked specimens shows that the structure of the brazing alloy within the crack is the same as the alloy in the fillet on the outside of the joint. These definitely indicate that there is no selective diffusion of any single element from the brazing alloy.

Figure 4 shows a micrograph of unstressed 18–8 stainless steel that has been soaked in a molten low flow temperature silver-brazing alloy for 20 min. at 1300° F. There are no signs of cracking.

Figure 5 shows the result of a few seconds contact with the same molten metal while the specimen was held bent in a vice; i.e., with the upper surface layer in tension. This is a prime example of what is termed by some as "stress-corrosion cracking."

The term "stress-corrosion cracking" implies that both stress and corrosion must be present for cracking to take place. Cracking during silver brazing has been frequently attributed to individual elements in the alloys, especially silver and zinc. In general, increasing the silver and zinc content of a silver-brazing alloy lowers the flow point. Consequently the lowest flowing alloys contain substantial percentages of both these elements. Conversely, the low silver or low zinc content alloys which appeared to decrease cracking during brazing have relatively high flow points. Thus, when brazing with these alloys, higher temperatures are required. The higher temperatures, in turn, will tend to relieve the stresses in the assembly being brazed and decrease the danger of cracking. Failure to recognize that the stress relief at the higher temperature is the true cause for the improvement has led to the erroneous belief that the silver or zinc selectively diffuse intergranularly and cause cracking. Any alloy which is a good brazing alloy must wet the surface of the steel before it can flow and give a strong bond. It follows, therefore, that cracking may occur with any brazing alloy irrespective of composition. However, the better the brazing qualities of the alloy and the lower the temperature at which it is effective, the greater is the danger of this so-called stress-corrosion cracking on highly stressed stainless.

The cure for "stress-corrosion cracking" is not in changing the composition of the brazing alloy, but in avoiding or relieving the stress in the areas to be silver brazed.

Fig. 5 Upper surface layer in tension with molten silver-brazing alloy applied for 20 sec.

Note the stress-corrosion cracking. 100 ×

TYPES OF STAINLESS STEEL

A question frequently raised is the relative ease of brazing the various types of stainless steel. Such steels as 302, 304 and other 18–8 types can be readily silver brazed. There is no difficulty in getting the silver-brazing alloys to wet and flow on any of these steels.

Commercial experience has shown that more difficulties may be encountered in brazing the straight chromium steels and particularly such steels as 416, 430 and 446. This is believed to be largely caused by the nature of chromium oxide film on the surface and the rapidity with which it forms. It has been found that this difficulty may be overcome by a little extra care in the cleaning of the steels before brazing. Cleaning should be done just prior to brazing, and in addition to degreasing should include a mechanical or abrasive cleaning of the joint area and particular care should be taken to assure that the surface is completely covered with an adherent flux film. If these precautions are taken, these steels will braze as easily and give just as strong joints as the lower chromium steels or the 18–8 types of steel.

The same procedures should be applied to the free machining types of steel, such as 303. Here, again the impression seems to be that the addition of sulphur or selenium interferes with the wetting of the steel by the brazing alloy. Many tests conducted on these steels

have shown that these steels may be brazed as readily, and equally good joints may be obtained as with any other type, provided that the fundamental steps outlined earlier in this paper are carefully observed. Note the strengths obtained in the tensile test results in Table 1.

The thermal expansion coefficient of austenitic stainless steel is about 40% higher than that of ferritic stainless or carbon steel. This fact has given trouble at times in the brazing together of different types of steel. This difficulty can be alleviated by varying the joint clearances to compensate for the expansion differences. For instance, in a tubular joint, if the inner member expands more than the outer member, a greater clearance must be allowed in the assembly or the clearance at the brazing temperature will be too small to permit the flow of the brazing alloy into the joint.

CORROSION RESISTANCE OF THE SILVER-BRAZED JOINTS

The corrosion resistance of stainless steel has been referred to earlier in this paper. An important factor which must be considered is the corrosion resistance of the joint itself. The corrosion resistance of the joint is vital not only from the standpoint of the ultimate use of the stainless steel but also in the pickling and cleaning procedures used during fabrication.

As most silver-brazed joints are of the lap or sleeve type, the area exposed to corrosion is customarily very small as compared to the area of the steel, and they will last a surprisingly long time under severe corrosive conditions. For instance, silver-alloy brazed stainless-steel frames and screens have been successfully used in handling sulphite pulps in paper mills.

A notable exception, however, is in the case of joints subject to strong nitric acid. The nitric acid will rapidly attack the joint. Nitric acid is frequently used both in numerous pickling solutions and in passification treatments of steel. The acid attacks the brazing alloy leaving it in a honeycombed condition, appreciably weakening the joint and also forming an ideal reservoir for absorbing and retaining corrosive solutions. Failures in service may often be traced back to such a condition.

Stainless steel, therefore, should never be given a nitric acid treatment for the purpose of passification of the steel after brazing as the damage to the joint far outweighs the advantages of the cleaning obtained by this treatment. Similarly, pickles containing nitric acid should be used sparingly and immersion of brazed articles should be reduced to as short a time as possible. Figure 6 shows, unetched, a section of silver-brazed joint in 18-8 stainless. Figure 7 shows an identical joint that has been pickled in 25% HNO_3 for 5 min. at 140° F. Note the spongy condition of the fillet, and the preferential attack at the interface. Fifteen minutes in the same pickle almost completely dissolved the brazing alloy.

The need for pickling after brazing should be kept to a minimum by the liberal use of flux on the heated areas surrounding the joint. Keeping the temperature of brazing as low and the heating time as short as possible also aids in reducing oxidation. If this is done the flux may then be removed in hot water and usually only a light pickle in a hot 50-50 concentration of hydrochloric acid is sufficient to clean the brazed article.

Prolonged exposure to chloride corrosion is harmful to some silver-brazed joints. While chlorides do not seriously corrode the silver alloy itself, they do attack the bond between some silver-brazing alloys and the steel, so that in a relatively short period the brazing alloy can be peeled off the steel. It has been found that the addition of a small percentage of nickel to the silver-brazing alloy will correct this condition and greatly increase the life of the joint. Therefore, where joints are to be exposed to chlorides, as in marine appli-

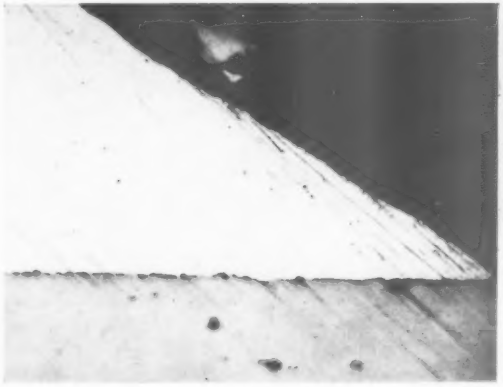

Fig. 6 An unetched section of silver-brazed stainless steel. 100 ×

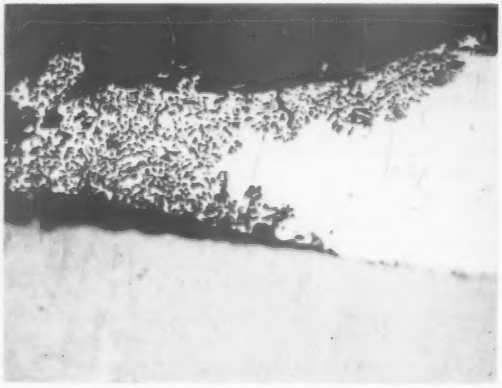

Fig. 7 An identical joint pickled in 25% HNO_3 for 5 min. at 140° F.

Note spongy condition of fillet and preferential attack at the interface. 100 ×

cations or in dairy equipment, a silver-brazing alloy containing nickel should be used.†

The Bureau of Food and Drugs of the Department of Health in one of our larger cities has recently completed some tests on various silver-brazing alloys. In those tests they found no contamination of foods by these alloys.

TENSILE STRENGTH OF BRAZED JOINTS

The strength of silver-brazed joints is a subject with many ramifications which has been reviewed elsewhere and will not be discussed in detail here, but a few general remarks may be of interest.

Assuming good brazing procedure, the strength of stainless-steel joints depends to a large extent upon the strength of the steel itself, i.e., the stronger the steel the stronger the joint that is obtainable. Thus the strengths may range from approximately 50,000 psi. for the softer, annealed stainless steels, to as high as 130,000 psi. for the higher strength steels. The effect of the strength of the steel on the strength of the joint is well illustrated by some recent tests on butt joints of $^3/_8$-in. diameter rod of Type 303 free machining steel brazed with Easy-Flo. Two lots of steel were tested as tabulated below.

Table 1

Lot 1		Lot 2	
Rockwell B hardness	*Tensile strength, psi.*	*Rockwell B hardness*	*Tensile strength, psi.*
80–85	51,100 max. 48,200 min. 50,000 av. (3 tests)	101–103	97,100 max. 85,400 min. 90,000 av. (7 tests)

The tensile strength of the stainless steel (Lot 2), as received, averaged 113,000 psi. with an average yield strength of 97,700 psi. The softer steel (Lot 1) had a proportionately lower strength and lower joint strength.

In both cases the elongation of the test pieces was about 1% in 2 in., indicating that the break occurred very close to the elastic limit in each instance.

As these tests were made on free-machining steels, they also confirm the fact mentioned earlier in the paper that selenium or sulphur-bearing steels can be brazed with results comparable to those obtainable with other stainless steels.

More specific details on the strength of silver-brazed joints may be found in a paper presented at the Western Metals Congress, A.W.S. Meeting, Los Angeles, Calif.,[3] and in the other references noted.[4,5]

† Proprietary alloy. Easy-Flo No. 3 (50% Ag, 15½ Cu, 15½ Zn, 16 Cd, 3 Ni).

CONCLUSIONS

We have discussed the principal problems peculiar to the brazing of stainless steel, viz., cleaning and fluxing, carbide precipitation, types of stress cracking, brazing of the different types of stainless steel, strength of joints and cleaning after brazing. The salient conclusions are:

1. Stainless steels require effective removal of oxide film before brazing.

2. There is a problem in carbide precipitation or sensitization to intergranular corrosion which may be avoided by

   (*A*) Minimum heating time.
   (*B*) Low-carbon content.
   (*C*) The use of titanium or columbian stabilized steels.

3. Silver-brazing alloys, contrary to some widespread beliefs, do not cause cracking in stainless steels unless the steel is highly stressed, and zinc, cadmium or silver do not selectively diffuse along the grain boundaries in any ordinary brazing time.

4. The pickling of brazed stainless-steel objects in strong nitric acid solutions should be scrupulously avoided.

5. Strong, clean, safe joints in stainless steel can and are being made with the procedures and precautions outlined here.

ACKNOWLEDGMENT

Helpful suggestions were made by the staff of the Technical Laboratory of Handy & Harman, Bridgeport, Conn., and by R. T. Jones, Engineer, and A. M. Setapen, Manager, Engineering Division, Handy & Harman, New York City. Dr. V. N. Krivabok, Metallurgist, International Nickel Co., New York City, kindly read the paper, making numerous helpful comments.

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Heliarc and Railroad Applications

Heliarc welding finds ready applications in the railroad field to the repair of cast-iron and aluminum parts. Exact procedures have been worked out

by H. E. Gannett

WITH mounting costs of operation in the railroad industry there is, more than ever, a demand for increased efficiency in the use of labor. There is also a need for welding processes that will help extend the economical service life of expensive component parts of mechanical units that make up primary transportation facilities. If railroads are to continue as successful enterprises, they must adopt and use the welding processes that more closely approach perfection in their adaptability to repairing and rebuilding the metals and alloy parts that become defective. Perfection in the sense used here does not mean to duplicate only the property of a casting at a point or area of breakdown through normal use, it means to be able to provide a deposit of integral material that can amply resist the forces in the breakdown area that caused the initial failure.

For many years we have been looking for a dependable process and procedure whereby the relatively cheap and concentrated heat of an electric arc could be used to weld cast iron and aluminum. From the welding operator's point of view, and from practical tests of hundreds of such parts that have been welded, there are many reasons to believe that the inert-gas-shielded arc process is a complete answer.

The more recently developed Diesel motive power and streamlined high-speed rolling stock are the result of intensive research designed to take advantage of any and all metals and alloys that have inherent physical properties most able to meet a vital service requirement in a complex structure. This newer-type equipment has greatly broadened the use of metals and alloys and subjected them to more constant and heavier service limits. Many of the welding processes and procedures were adequate for the older type equipment but as newer types displace older types, it is found that the quality requirements of welding placed several of the older welding processes and procedures in a secondary position. Very fortunately, the inert-arc-welding process, preferably using argon, has been developed to a high acceptability with which to reclaim many of our most difficult parts.

Other articles and papers cover details of equipment and this paper will not attempt to cover that general field. In the previous mention of argon, the word "preferably" was used because argon has a thermal conductivity of 0.0000389 as compared to helium 0.000339. (This value is based on calories per second per square centimeter across one centimeter.) This is a ratio difference of 10 to 1. This difference, we believe, increases the capillarity of the molten metal, a very desirable condition in any building-up operation. It is our opinion that no other fusion welding process provides fluidity of molten metal as does the inert-gas shielded welding process, using argon. This is especially noticeable on cast iron and aluminum, both of which flow quite similar to silver in a fluid state. Due to the increased capillarity it is not difficult to weld aluminum overhead and vertically. Also due to the fluidity and increased capillarity there is a minimum of waste material as the impurities readily float to the surface and the fluid metal readily joins in the molten pool.

Cast iron and aluminum welding by other processes are essentially "puddling" operations in which the filler material is used to push the molten pool to full depth, or else a paddle of foreign metal is used to spread and smooth the weld puddle. Any such puddling is unnecessary with the inert-gas-welding process and it has been found detrimental in the case of cast iron. For if the cast-iron filler rod is pushed to the bottom of the molten pool, gas pockets will form and a porous condition will likely result. In our procedure we only contact the surface of the molten pool with the filler rod. The etched samples on the photos will show the soundness of the deposited cast iron (Fig. 1).

Our practice in all possible operations is to position the work so as to weld downhand. The parts are first preheated either in an oil furnace or by use of a preheating flame as the photos will show. In the case of cast iron, the parts are then removed into insulated workcases with openings through which the part may be welded with only a small area exposed.

There is sufficient heat retained to complete the weld

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Figure 1

and the completed part is immediately postheated. When it is removed from the postheating furnace it is placed in insulated cooling boxes which permit complete cooling in about 24 hr. The parts being reconditioned are easily handled in metal asbestos-lined boxes that hold the preheat and postheat. The boxes are easily positioned at the correct working height. At each welding station an air curtain is provided that shields the welding operator from much of the heat emanating from the boxes. These conditions promote speed and better-quality work and also are a factor in the reduction of required skill on the part of the welding operator.

The procedures for welding cast-iron cylinder heads are as follows: The heads are first tested for water leaks and any that are found are marked. They are next magnaflux tested to locate any cracks in the stud holes that bolt the head to the cylinder liners. Most injector holes are drilled $1^7/_8$ in. in diameter to a depth of $^1/_2$ in. with beveled circumference. Figure 2 shows a head ready for welding. Note the drilling of the injector hole and the chipped and ground areas between the valve seats and the injector hole, the hole in the latter is drilled deeper than $1^3/_8$ in. or to the bottom of any cracks. The cracks are then chipped or ground out down to the water space. Grinding with a thin emery wheel is preferred. Figure 3 shows the furnace in which the heads are preheated, using an air-kerosene flame. In this particular view the operator is removing a head after postheating. Using the chain hoist the head will be lowered into the asbestos-lined box, the cover will be put on, and the part will cool until the next day.

The heads are preheated to about 1500° F. in this same furnace. After heating they are placed in a box like the one shown in Fig. 4. This asbestos-insulated box is fastened to a jig that permits the part to be revolved and also turned 180° so that the part may be placed on its side. The box is $15^1/_2$ in. in diameter, 9 in. deep and is welded up from 14-gage steel. The covers you see here are also insulated and have a 3-in. flange. The cover at the left has an opening through which the welding is done at the injector hole. The cover on the right has a 5-in. hole through which the valve seats are rebuilt. This lid is easily turned by the handles so that each seat is successively welded. The relationship of the center hole to the injector hole is seen in Fig. 5.

If the injector hole is to be rebuilt, the first step is to place a steel cylindrical plug into the hole and tack weld it into place, see Fig. 6. The plug will be seen on the end of the welding rod being placed in the injector hole. Inert-gas-shielded arc welding then is used to make multiple passes around this plug and across the cracks to the valve seats. The injector hole is being welded in this photo (Fig. 7).

In building up valve seats each seat is first melted down completely around the circumference with the inert-gas arc process without any rod being applied. This has been found to be important as the seat will be defective when finished if this is not done. Figure 8 shows the operator welding through the valve-seat cover, adding cast-iron filler rod at the front of the molten puddle. Care must be taken not to dip the rod as this has been found to cause harmful porosity.

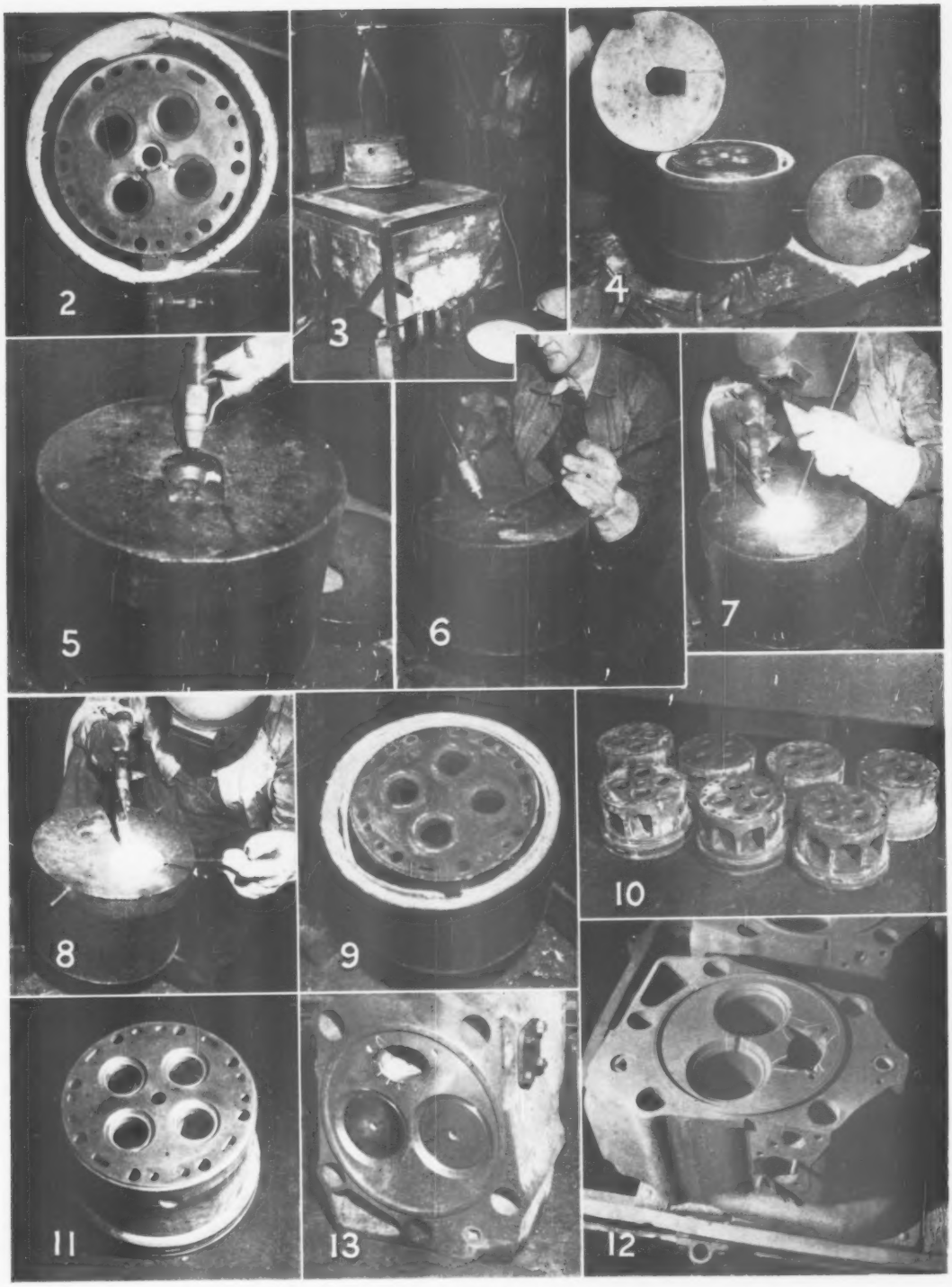
After the valve seats and injector hole are rebuilt, the cylinder heads that have cracks at the side in the stud holes are placed on their sides in an insulated box so that the stud hole can be welded downhand. A copper backup strip is used in the stud holes to prevent the metal from plugging up the holes. Figure 9 is a completed head as-welded ready for the postheating treatment shown in a previous photo. Figure 10 shows seven heads that have been welded and removed from the cooling boxes. Note that stud-hole welding is seen in several of the heads in this view. Another point to notice is that most of these heads have rebuilt valve seats only. With the exception of one head in the back row, it was not necessary to weld up the injector hole as there were no cracks between it and the valve seats.

Figure 11 is a finished-ground reconditioned Diesel cylinder head ready for valve assembly. The line between weld metal and parent metal can hardly be detected even on close examination of the head itself.

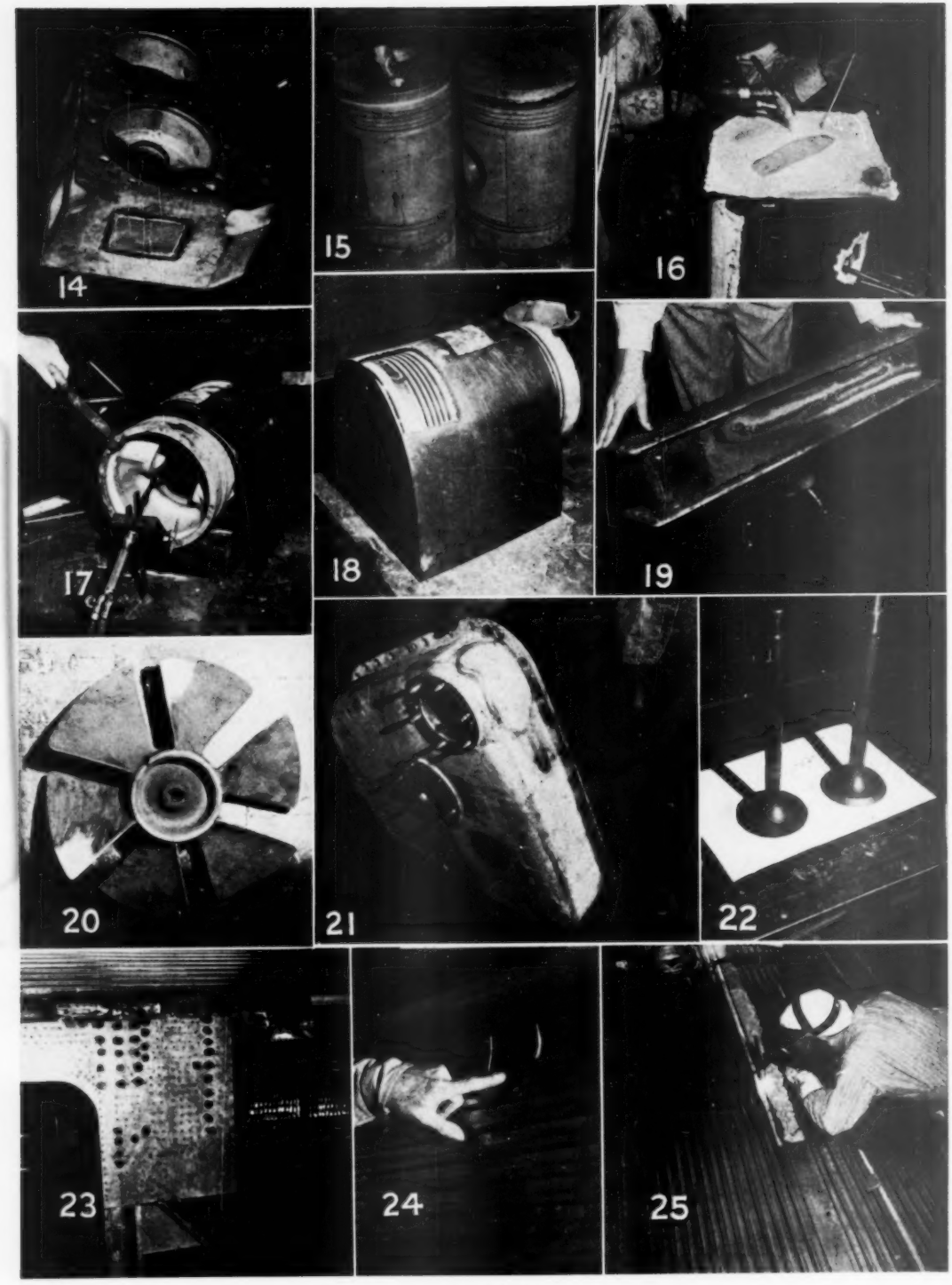
Preheating time on this head is about 20 to 25 min., welding time from 40 min. to 1 hr. and 30 min., and postheating time is about 15 to 20 min. These reconditioned heads give service life equal to that of a new head. Cost of welding and machining runs in the neighborhood of $25 against a $59 cost for a new head.

The second type of cylinder head which is being profitably repaired by the inert-gas arc-welding method is the one shown in Fig. 12. Note the ground-out areas of cracks at the valve seats and at the opening of the precombustion chamber. Procedures for repair of these cast-iron heads are quite similar to those just described in detail. A finished, repaired head with valves installed is shown in Fig. 13. Note the stress-relief cuts made in the opening of the precombustion chamber. These cuts help prevent frequent cracking in this area.

The gasoline motor-car head shown in Fig. 14 is also repaired with inert-gas arc welding. The material is aluminum impregnated with a phenolic resin and it has



Figures 2–13



Figures 14–25

been found impossible to make repairs with any other process than inert-gas arc welding. A patch on the side of this head was readily welded in and the same process is used to build up valve-seat areas for the insertion of new valve seats.

In Fig. 15 the cast-aluminum Diesel piston on the left has been prepared for inert-gas arc welding. The one at the right has the crown welded and machined and the top ring groove is welded but unmachined. Cracks in the crowns of these pistons occur frequently in the areas shown and the ring grooves become badly worn. They cost about $157 to purchase and they can be reconditioned for about $15.

Before welding, the crown on top is dished down from 0.001 to 0.006 in. The top is drilled and chipped out to remove the cracks and permit the contact of the welding electrode inside the water-cooled cup. Ring grooves that are to be built up are machined out with beveled edges to permit entry of the cup. Using a No. 80 tip the piston is oxyacetylene preheated to 500° F., Fig. 16. The part is then placed in an asbestos-lined box to hold the heat and while welding of the top is performed the preheat is held by the flame from a blowpipe fitted with a No. 20 tip. Several passes are necessary to repair the extensive defects found in these parts.

Figure 17 shows the turning jig and the protective cover used in building up the ring groove. Also seen are the heating blowpipe and the handle used to turn the piston. Figure 18, a view of the same setup, shows the exposed part of the piston with the deposited metal in a ring groove. On the edge of the table, lower left, is the pipe which releases the curtain of compressed air which makes for welding comfort.

In this welding, superimposed high-frequency current is used at 300 amp. with a $^{3}/_{16}$-in. electrode and an argon flow of 12 liters per minute. Finished pistons are allowed to cool in a covering of asbestos paper. Parent metal of the piston is 64 Brinell as compared to 48 or 54 Brinell for the deposited No. 23 aluminum rod metal.

The next three illustrations will show other representative aluminum Diesel parts that are efficiently repaired by inert-gas arc welding. Figure 19 shows a cracked radiator cooling header. The damaged blades of this cooling fan, Fig. 20, were replaced with welded metal. Gear-box casing in which a prepared section of aluminum plate was welded are shown in Fig. 21.

Turning now from aluminum, in Fig. 22 are shown two high-alloy Diesel valves reclaimed by inert-gas arc welding. The valve on the left shows the as-welded appearance, that on the right is finished ground. In this rebuilding, about $^{1}/_{8}$ in. thickness of MW rod is deposited. It is possible to rebuild these valves at a fraction of the cost of new valves and they give service equal to new.

Considerable information has been published on the use of this process on unstressed stainless steel members. We have had excellent results in its use on stainless under stress. At points where spot welding will not reach, the spot welds were reinforced by drilling holes through the sheet and welding the sheet to the heavy support members through the holes (Fig. 23). The chalk-circle areas are the welds made in this car by the inert-gas arc-welding process. The clean finished result, Fig. 24, obtained by this process is clearly illustrated by this weld in stressed sheathing on a stainless-steel coach. Figure 25 shows the operator making an edge weld in thin stainless on a coach roof. In the repair work on the growing amount of stainless passenger equipment on our railroad we place great reliance on the inert-gas arc-welding process.

As to the process considered as a whole, we have used it on 20 different stainless steel applications, on 14 aluminum, on 4 alloy steel and on 4 cast-iron parts. We feel certain that the field for the process has much room for growth in the railroad industry. As a matter of fact, we have stepped up our current capacity to 1000 amp. in preparation for limitless expansion in heavy applications.

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(*Continued on page 1165*)

Economical Design of Welded Buildings

Maximum savings are possible when the structure is designed for welding. Trusses, girders and unsymmetrical sections offer the best opportunities for economy

by Robert E. Robertson

INTRODUCTION

SINCE the war increasing interest has been shown in the use of welding by the construction industry. All-welded construction is meeting with the same enthusiastic acceptance in the building field that marked the introduction of reinforced concrete four decades ago. This growing acceptance of the techniques of all-welded construction proceeds from the same basic reasons that have been responsible for the widespread use of reinforced concrete. The motivating force in both cases has been economy and flexibility of a monolithic or mono-steel construction.

The versatility of a structural system that may be virtually hand tailored by the fabricator to an unlimited range of conditions opens a new frontier for the economy minded designer who has long been fettered by "stock catalog" members. Furthermore, the minimization of construction noise and vibration is usually desirable and is often a compelling attribute of welding.

Be that as it may, the question of whether or not to adopt any new construction method depends on many factors. Everything else being equal, the more economical method of construction will obviously recommend itself. In order to cut construction costs, savings must be made in one or more of the following ways.

1. By reducing material.
2. By cutting shop fabrication.
3. By saving labor at the erection site.

Under many conditions welding can and does effect savings in each of the above.

The large material savings realized are of prime importance. In a design executed for welding, the savings can amount to as much as 1/4 in certain structural elements. Quite commonly 1/4 reduction in tonnage is achieved.

The shop fabrication is simpler in a welded design. There is less material to be handled. More people can work on it at one time. Most important, entire processes, such as punching and drilling, can be eliminated.

Savings at the erection site could be substantial. The fact that they have not been offers a challenge to the construction engineer. An important fact to be remembered, however, is that MAXIMUM SAVINGS ARE POSSIBLE ONLY WHEN THE STRUCTURE IS DESIGNED FOR WELDING.

Whether or not welding is to be used in a particular structure must be decided early in the planning stages. Experience has shown that it could be used in more than a majority of cases. As good welding practice becomes established in both drawing room and shop, welding will tend to supplant riveting. It therefore behooves the fabricator as well as the designer to originate economical methods in the shop and field. Already several erection systems have been developed that show promise of what may be done if erection methods as well as structural members are designed for welding rather than merely adapted.

DESIGN

Basically the economy of welding over riveting is derived from the former's adaptability to construction that is continuous. Since it is impossible to roll complete steel structures to achieve this continuity, the nearest approach is to develop a connecting technique which efficiently joins the mill-rolled and shop-fabricated pieces into a nearly continuous structure. Welding does this and does it without the addition of appreciable connection material. As Gilbert D. Fish so aptly states in his *Arc-Welded Steel Frame Structures*, "Welding is essentially a fusion of metal resulting in true continuity of material and cannot be equaled in strength by any other joining method thus far suggested by research in properties of metals."

We must look to the designer to develop through sensible stress analysis this inherent strength of welded

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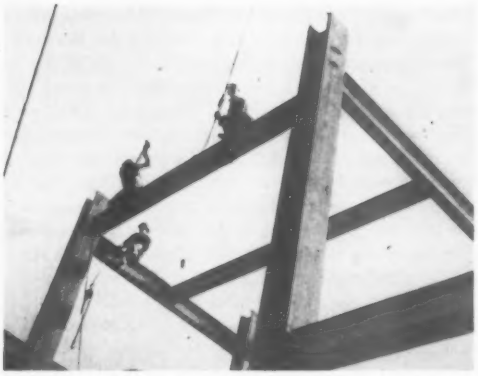
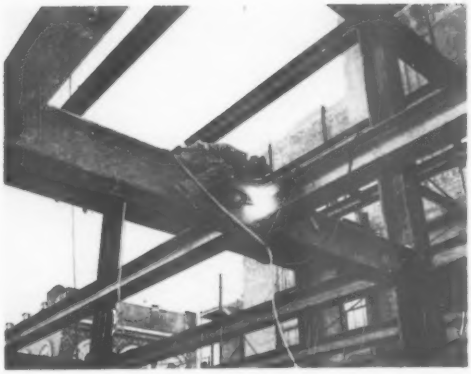


(a) Erection



(b) Welding

Fig. 1 Streamlined building construction

construction. The natural rigidity of welded joints has been long considered a deterrent by some engineers. However, the more logical approach would appear to be the adoption of design methods based on this highly desirable joint continuity. On a rational basis, the engineering analysis of a welded structure should be no more difficult than a similar design in reinforced concrete.

ANALYSIS OF ECONOMIES

The engineer designing welded structures for economy will find his most fruitful field lies in better utilization of main material. This may be achieved in two ways:

1. Through equalization of stresses in framing.
2. Through minimization of strength-loss due to punching and drilling.

Simplest application of this more efficient material use through welding would appear to lie in members predominantly tensile since strength loss due to rivet holes obtains mainly in tension areas. Sizable savings may also be made through reduction of connection material in members with a multiplicity of subjoints.

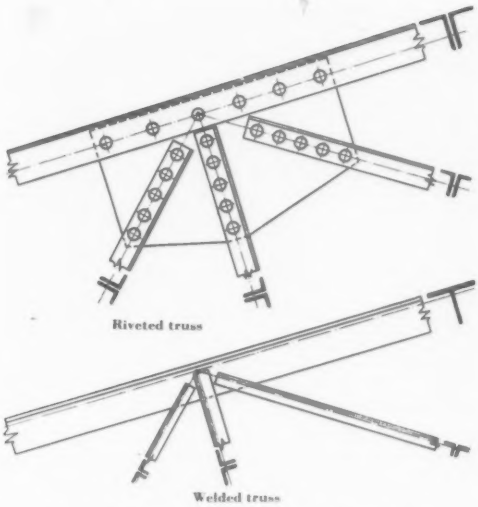


Fig. 2 Comparison of welded and riveted truss

From this it can be surmised that such structural elements as trusses, plate girders and the unsymmetrical sections used in composite construction comprise the fields of greatest promise for welded design. The efficiency of welding in construction of trusses is principally derived from utilization of gross section of individual members and the elimination of gusset

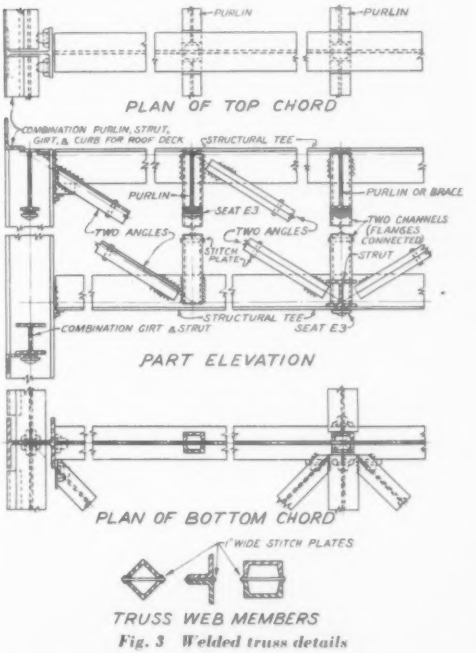


Fig. 3 Welded truss details

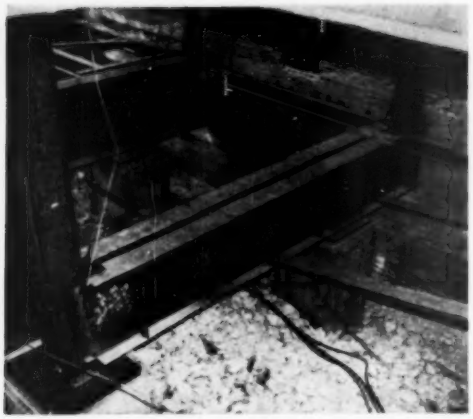


Fig. 4 All-welded twin girder used to provide setback of building column in the sub-basement of a telephone equipment building recently constructed for the C and P Telephone Company of Virginia, in Richmond

In order to avoid costly removal of an existing underpinning wall, it was necessary to offset one entire row of columns. The loads to be carried were heavy, the building being designed to carry equipment at 150 lb. per square foot. Furthermore, depth of construction was limited by headroom requirements

plates. In the average roof truss 20% of the weight is consumed in detail pieces. The economy of a construction which eliminates these pieces is evident. Side by side comparison of riveted with welded design of the same trusses in Fig. 2 readily shows the obvious advantage of the latter. It must be remembered, however, that substitute sections must be selected with caution to avoid extra mill costs. Structural tees and wide flange beams often involve such extra costs which must be weighed against the material saved.

Other examples of welded truss construction and interesting design details are shown in Fig. 3.

GIRDERS

Typical of what may be done with welding to meet varying requirements in the component parts of a plate girder is aptly illustrated by the twin transfer girders shown in Fig. 4. This photograph shows an all-welded twin girder used to provide set back of building columns in the sub-basement of a telephone equipment building

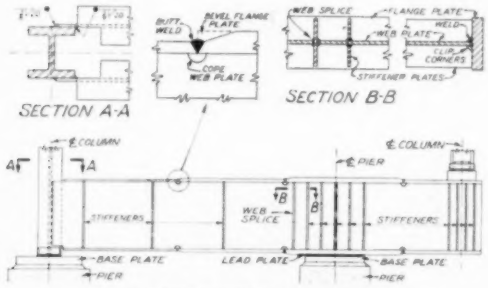
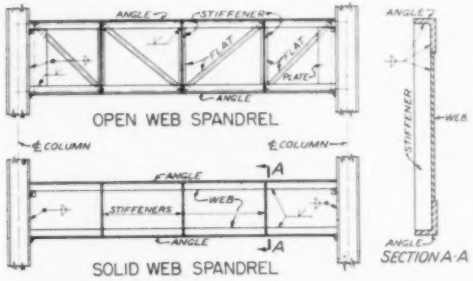


Fig. 5 Details—welded transfer girder

recently constructed. A 14-inch by 54-in. section was chosen, web thickness varying from 5/8 in. to 3/4 in. Flange requirements varied from 1 in. by 14 in. to 3 in. by 14 in. In each case the conditions were met by butt welding plates of different thickness—the thicker plate being tapered adjacent to the weld to meet the thinner plate. Basically the girders were composed of single upper and lower mono-steel flange plates continuously welded to a mono-steel web plate. Submerged-arc process was used for this joining in the shop. Stiffener plates were attached by intermittent fillet welds by the same process. See Fig. 5.

A troublesome detail to the structural engineer is the support of stone or brickwork across the multiple openings of the wide and often continuous windows in the modern office building. This can be solved in several ways.



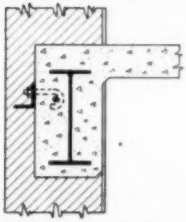


Fig. 6 Spandrels

(a) Open-web spandrel
(b) Shelf angle attachment to fireproofed beam spandrel

In steel skeleton framing, a continouus beam called a spandrel is usually run from column to column around the exterior of each floor at window head height. This beam supports the stone, brick or concrete by means of a shelf angle which is either integrally attached to the spandrel or bolted to the fireproofing surrounding the spandrel. Figure 6 (*a*) shows one of the first type. This spandrel section was obtained by the joining of angles and plates to form a deep open-web spandrel beam. Architectural spandrel was constructed and held in place by reinforcing bar threaded through the stiffener angles. Fig. 6 (*b*) shows method of attaching spandrel shelf angle to a fireproof spandrel beam of the type shown in Fig. 13.

Numerous examples of use of welded plate girders in building construction could be cited. However the use of girders is by no means limited to buildings. Girders probably find their most widespread application in bridge building. An interesting use of this same mono-steel plate construction is illustrated in the design of the through girder railway bridge shown in Fig. 7.

The girders in question are 120 ft. in length and vary from 10 ft. $6\frac{1}{2}$ in. in depth at the haunch to 9 ft. $8\frac{1}{2}$ in. mid span. Varying flange and web requirements are again met by butt welding of plates of different thicknesses rather than the usual inefficient laminating of plates and the loss of section strength due to multiplicity of rivets. An estimated savings of 30 tons of $12,000 (at $400 per ton) will probably be realized on this project by this technique. A more esthetic effect was obtained through arching of girders and increasing thickness of flange plates upward. This was possible only through use of welded construction.

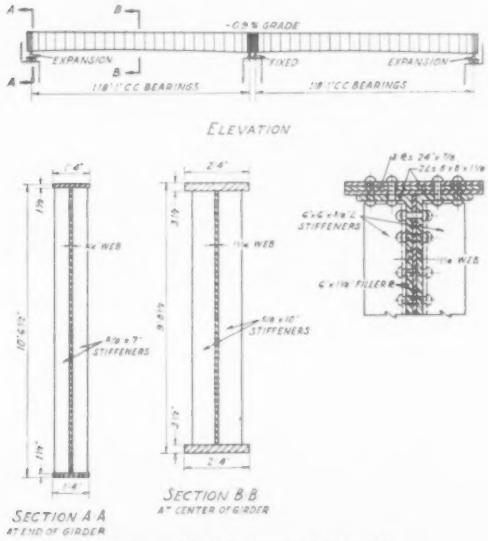


Fig. 7 Welded railway girder bridge

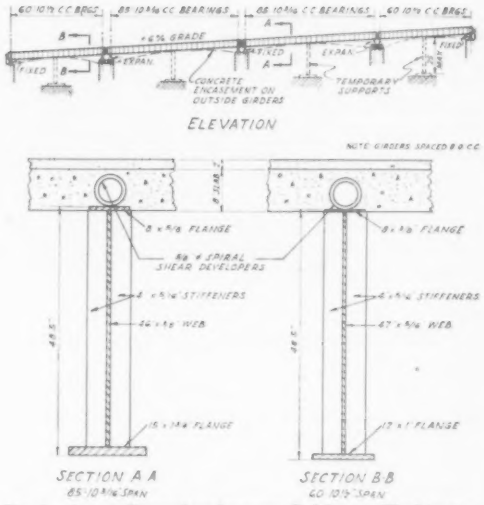


Fig. 8 Annapolis road underpass—Baltimore-Washington expressway

COMPOSITE CONSTRUCTION

A field in which increased building costs have accelerated interest is the utilization of concrete for load-carrying purposes in structural systems in which concrete has heretofore been used but for fire or weather-proofing or perhaps for transverse slab construction. Reference is made to what is commonly called composite construction. Composite construction has been used in bridge building but to a limited extent largely because of the requirement for unsymmetrical structural steel sections.

The concrete is used to carry compression stresses and the steel members carry all of the tensile stresses. Quite naturally this requirement in a steel member is best met by an unsymmetrical section. The absence of these from regularly rolled shapes and the reticence of the bridge engineer to accept welded fabrication have worked to delay acceptance of composite construction. If unsymmetrical sections were readily available, I believe that the building construction industry as well as the bridge designers would adopt this economical combination of construction materials. What can be done along this line using an unsymmetrical girder fabricated by welding is shown in Fig. 8.

In the main girders of this 4-span highway bridge, an 8-in. by $\frac{5}{8}$-in. top flange was connected to a 15-in. by $1\frac{3}{4}$-in. bottom flange by a $\frac{3}{8}$-in. web plate 46 in. deep. Manual welding was found to be more economical than submerged-arc welding in this case because of the small weld sizes required. Less moving of main material to position for welding was likewise required by hand welding. Here manual welding was selected for all but the splicing of the web plates. This design utilized an 8-in. concrete floor slab to develop entire

compressive stress requirements. Five-eighth-inch spiral shear connections, as manufactured by the Porete Mfg. Co., were used.

An estimate for this job using conventional construction was 362 tons. Composite construction required 142 tons, saving 220 tons. This could have amounted to 100,000 dollars had the fabricator not been subjected to extra mill charges. Actual savings are estimated at $65,000.

It is to be noted that the design has been accepted by the Public Roads Administration and the project is now under construction.

MULTISTORY BUILDING FRAMES

In the conventional multistory building framework of steel columns and beams, the economies offered by welding are of an entirely different type than those obtained in girders and trusses. At least 75% of the steel tonnage is in compression. Most members are rolled shapes. Subjoints are at a minimum. Therefore the elimination of connections and other detail pieces offers slight return. The designer must explore other aspects of the problem for tangible results.

If, through increased efficiency in joining, the number of detail pieces has been reduced to a basic minimum, the remaining question is this: Can the main material be more fully utilized and equally stressed in all components of the framing? This can be done first by assuming in the analysis that the various members of a structural system are continuous and then by utilizing an assembly technique that makes effective this assumption.

The obvious advantages of continuous construction are best achieved in a welded design. Heretofore the high cost of welded fabrication and assembly has dissipated many of the design economies anticipated. In this aspect, erection methods developed by the author's partner are touched upon as examples of what may be done in effecting savings in the shop and field assembly of members for welding.

Before investigating the possibility of using welded construction in a particular building, the general framing scheme must be decided upon. The effect on this framing scheme of the several assumptions that can be made as to joint rigidity must be studied before a decision as to use and extent of welding can be reached.

In the two buildings of recent all-welded construction, the decision to use welding was arrived at for diverse reasons. The design problems and loading characteristics radically differed. But the results in economy were quite uniformly pleasing. As a background for the presentation of design details, fabrication and erection methods, stress analysis involved in multistory building frames is sketchily reviewed. Solutions evolved on two projects under discussion are cited.

TELEPHONE BUILDING

The first project, a 14 to 16 story telephone equipment building* posed the question of how to obtain shallow, long-span construction under relatively heavy loading with the least possible noise and vibration. The latter requirement was necessitated by the proximity of switchboard and delicate automatic dial equipment. The problem was further aggravated by the fact that 20-in. girders and 14-in. beams had been used in the existing construction and its floor levels and ceiling clearance had to be matched in the new building, although 18-in. and 12-in. sections were the only comparable shapes economically available.

Preliminary investigations indicated the following weight savings could be realized in a 20- by 20-ft. panel.

1. 1000 lb. saved through elimination of connecting pieces.
2. 1650 lb. saved through continuous and rigid framing.

* Addition to Grace St. Bldg., C. and P. Telephone Co., Richmond, Va. Fabricator, American Bridge Co.

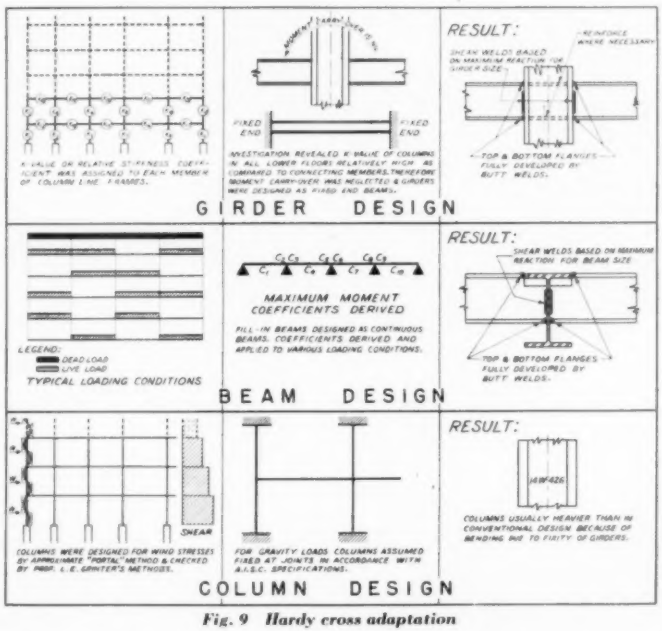
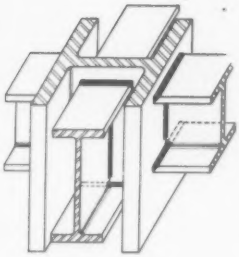


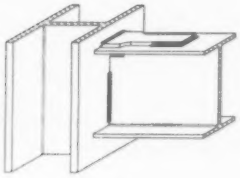
Fig. 9 Hardy cross adaptation

(a)



(b)

(c)



(d)

Fig. 10 Beam to column moment connection

(a) and (b) Rigid type; (c) and (d) semi-rigid type

This meant a possible savings of $60,000 in the entire structure.

The Engineer based his recommendation for welded rigid-frame construction on this study, and the owner's requirements for minimization of noise and vibration. This met with ready acceptance by both owner and architect.

A.I.S.C. specification clearly defines and unqualifiedly permits rigid frame construction.

Having decided that welded construction was indicated and a rigid frame would be used, the next problem was the detailed stress analysis. In this project, a modification of the classical method of Prof. Hardy Cross, so widely used in the design analysis of continuous reinforced concrete structures, was adopted. Figure 9 shows the schematic outline of the adaptation of this design method.

As may be seen, the analytical approach adopted is practically the same as might be used for a reinforced concrete building.

Because of the similarity of floor framing where beams framed to girders or other beams (fill-in beams), it was decided to derive coefficients to compute the maximum design moments. The coefficients were derived by moment distribution for the various spans and loadings, and then used for all similar spans. All column lines were utilized for wind-bracing bents.

A preliminary design disclosed that in general the columns for the present addition of the building (lower 8 floors) would be considerably stiffer than the girders or beams framing thereto, which meant that little unbalanced moment would be carried over from beam to beam. The heavy columns were of course due to provision for future floors. Therefore all beams or girders framing to columns were figured for the fixed end moments due to vertical loads plus the fixed end moment induced by wind. Wind moments and shears were figured for present and future addition by approximately portal method. After thus obtaining an idea of the magnitude of forces involved, assumptions were checked by the more exact method of Prof. L. E. Grinter.

Columns were designed for bending and direct stress under the A.I.S.C. specifications. An unusual condition encountered was the disproportionately large end moments caused by wind as compared to those caused by the fixed end connections of the beams and girders under vertical loads. In general, all connections provided for both moment and shear. However the ends of floor beams framing to spandrel girders were provided with shear connection only. This was also the case with miscellaneous stair-well and elevator-shaft beams throughout the building.

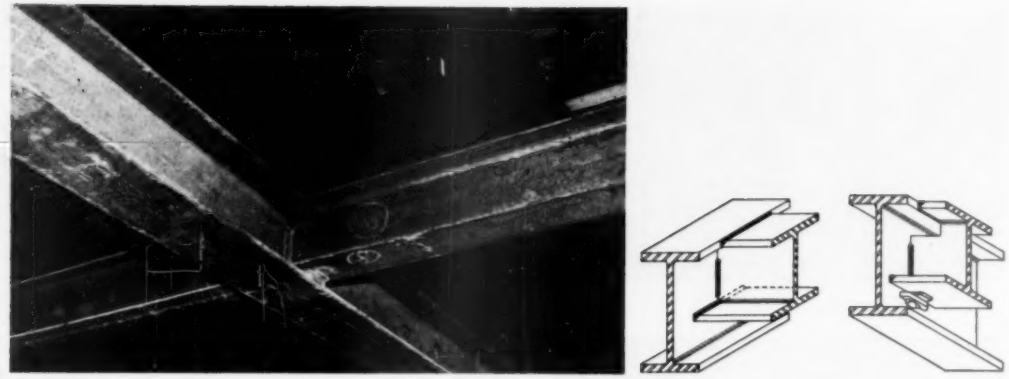
NEWSPAPER PLANT

The other project of current construction interest is a manufacturing and office building for a large daily newspaper.* The building is 300 by 400 ft. and is subject to the heavy loads of printing presses and equipment. The building is generally 6 to 12 stories in height.

In common with the telephone equipment building, rigid frame construction was used except that joints were designed to yield within the elastic range under stresses due to gravity loads. Such a joint is shown in Figs. 10 (*c*) and 10 (*d*).

Some thought was also given to the use of cover plates at the fixed and continuous ends of beams and girders to allow the reduction of the members at midspan. (Since moment at the support due to vertical

* Sun Paper Publishing Plant, A. S. Abell Co., Baltimore, Md. Fabricator, American Bridge Co.



(a) (b)

Fig. 11 Continuous beam to girder connection

load plus wind usually governed the selection of the section.) After some study by the fabricator of the relative cost of the steel saved and the increased welding and handling required, the idea was rejected as being of doubtful productivity under the conditions obtained in that particular shop.

Except as noted, beam and column details similar to the first building were used throughout the construction.

DESIGN DETAILS

So far it may be seen that design for welding does not differ greatly from design for conventional construction except that, in the analysis, continuity is wholeheartedly adopted and rigidity fully utilized. Having made these design decisions, the full realization of the advantages of all-welded construction lies in the vigorous adherence to these basic assumptions of continuity and rigidity down to the smallest detail of construction. The familiar devices and conventions of riveted connection will not suffice. Details developed for welding are unique. A good sense of streamlining and the avoidance of notches and sharp angles will guide the welding designer around many difficulties. Examples of such details are shown in the adjoining photographs and sketches.

TYPICAL WELDED DESIGN DETAILS

Figures 10 (*a*) and 10 (*b*) show a typical beam-to-column moment connection made by butt welding the beam flanges directly to the column web or flange. Shear connection is made by fillet welds each side of web. Where required, column web and flange are reinforced by stiffener plates to column directly opposite the top and bottom flanges of the beam.

Figures 11 (*a*) and 11 (*b*) show a beam-to-girder connection. Fillet welds each side of the beam web, preferably made about center of the beam web, are employed to carry the fixed end reaction. Length of these shear welds are usually shown in a table. Top and bottom flange of the beams are fully developed by butt welding directly to the top flange of the girder and to the girder web and thence to the beam flange opposite, thus obtaining full continuity.

Figure 12 shows the rather intricate connection made by framing of double girders to a single column; double girders required because of either floor openings or floor depth restriction.

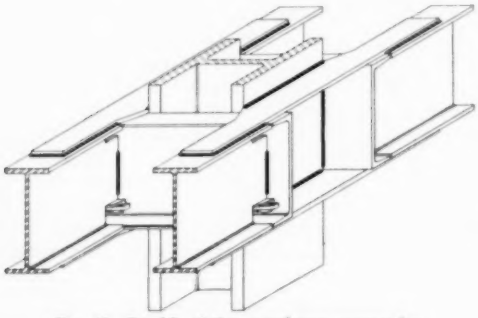
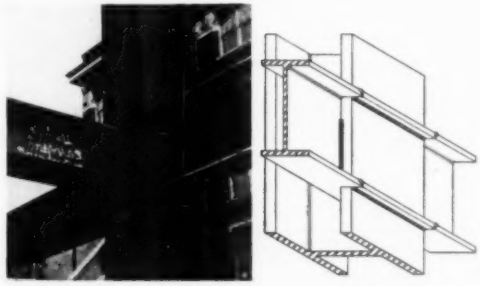


Fig. 12 Double girder to column connection



(a) (b)

Fig. 13 Developing spandrel continuity at column

Figures 13 (*a*) and 13 (*b*) show another interesting development of welded construction details as applied to the conventional spandrel used in office building construction. Shown is method of obtaining spandrel continuity about the outside flange of an intervening column.

Figures 14 (*a*), 14 (*b*) and 14 (*c*) show a streamlined column splice. This joining of two 426 lb. per ft. 14-in. columns is a far cry from the usual riveted construction. Single vee-butt welds were used, maximum size $^3/_4$ in. Full area of remaining section of both upper and lower columns was milled for bearing. Lack of uplift because of heavy dead loads precluded necessity for additional welding. Note erection bolts still in place in the lugs at the four corners of the columns. These shop-welded lugs were the only connections necessary to hold the columns in place during erection until field welding could be accomplished.

PREPARATION OF DESIGN DRAWINGS

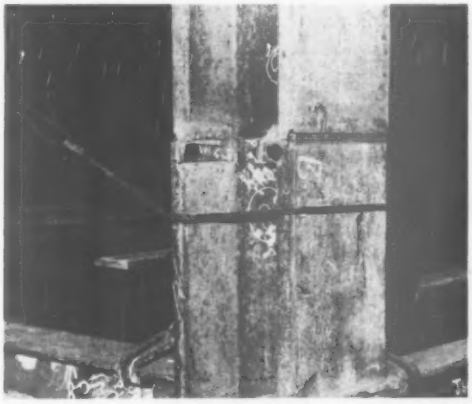
Significant differences exist between drawings for a riveted and welded job. The most outstanding difference is the extent of detailing required. Due to lack of industry-wide standardization, the drawings for a welded structure must show complete information for all special pieces such as trusses, plate girders, etc. In a riveted building, "standard beam connections" can be specified and the shop detailer designs connections for given stresses. In a welded job, the detailing of the connections can be done in either of two ways. Typical connection of the type desired can be drawn and beside it a list of the connection welds for each weight of section used. If this would cause too much waste of weld metal, another method may be used. It might be noted here that waste of weld metal is not viewed with as much alarm by shop men as heretofore. Shop men now realize that preparation for special and individual welds may be far more costly than some slight oversize resulting from standardization. In the second method typical detail of type of connection is again shown on design plans noting the allowable stresses and design procedure for detailing individual welds. The fabricator's draftsman then completes the connections as he details each beam. The first of these two methods was used in the buildings being discussed.

FABRICATION

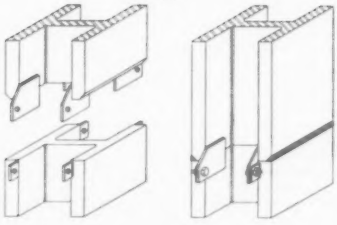
Shop Drawing and Layout

The shop layout of material for welding is simple. Pieces to hold the material in place until welded can be either fabricated or manufactured. Detail drawings show welding connectors rather than the usual riveted connection angles. Holes are either at a minimum or entirely eliminated. In detailing beams, connectors are shown as the out-to-out measurement between

(*a*)



(*b*)



(*c*)

Fig. 14 Splicing columns for welded construction

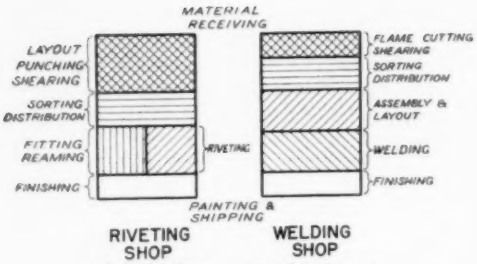


Fig. 15 Comparative shop layout

supporting members in the same manner as holes are shown. In detailing columns, the connectors must be at proper elevations. Connectors are laid out directly on the steel, clamped, tack welded and finish welded. By working on several main members, one after another, it is possible for a welder with a helper to turn the steel over so connectors can be welded to main members without moving them from the original layout positions. With connectors welded in place, shop assembly is done. Comparison of the operations required in shop work using such connectors reveals that far less operations are required than for riveting. However, certain economies accruing from automatic spacing rivet equipment tend to overcome these advantages of welding in shops so equipped. Connectors also save many operations in field erection.

Shop Facilities Needed

As in riveted work, the layout of a shop for handling welded work would depend on the type of product which is in turn controlled by market demand. In general, welding requires less shop area for preparation of material as shown in Fig. 15, but does require a proportionately larger space for the assembly-connecting area and the welding area.

Requirements for other areas of a welding shop are quite similar to those for a shop for riveting. Equipment for a shop built for fabrication by welding only is less expensive than that for a shop for riveted work. For instance, I know of a small shop with but $50,000 plant investment that turns over $500,000 worth of work per year. However, some of the equipment used for riveted work can make large reductions in the costs of parts for welded fabrication.

Inspection

All shop work should be inspected. It is the general practice that welding be done only by men who have been qualified by some recognized testing laboratory in accordance with standards set by A.W.S. There is no simple way for testing welds comparable to the tapping test given riveted work. Careful visual inspection of the welds coupled with observation of the welder at work has been found adequate. The development of welder certification on a nation-wide basis through some central board would be a big step forward.

ERECTION

In welded steel assembly, the sequence of erection is exactly that of any structural framework. Columns are erected first as shown in Fig. 16 (*a*). Figure 13 shows how they are held in place until welded.

Steel beams and girders are raised to their correct positions at the connector on a column or beam. When the beam is slightly above the connector as shown in Figs. 16 (*b*) and 16 (*c*), the beam is lowered so that the clip or angle engages the connector opening. The beam is then lowered into final position. The connectors not only act as supports for the beams but produce the same effect as temporary field-erection bolts. Because connectors on ends of beams are worked to neat dimensions between columns, the columns automatically become plumb as the beams and girders are attached to them. In case any portion is not plumb, it can be plumbed in the conventional manner. If shop errors are found during erection, it is easy to burn off a connector and put on a new one in proper place. Erection speeds with this method are high. The Lynchburg, Va., Allied Arts Bldg. was erected at a rate of 3 floors a week; the Richmond, Va., Telephone Bldg. was erected at 2 floors a week; at the Sun Bldg. 510 tons in one week were set with two derricks.

As high as these speeds are, greater speed could be made if certain delaying factors were eliminated. Much time is lost by the "raising gang" waiting for the welders to make the framework directly under the new derrick position safe for erecting loads. I believe that better programming of the construction sequence and use of more welders will reduce this loss.

Field Welding

The mechanics of specifying and obtaining the proper welds in the proper places is simple. The welding foreman is supplied with a table of required welds, beam by beam, floor by floor. The foreman usually marks out with a crayon the welds required at a particular location. One foreman can supervise 6 to 8 welders and at the same time tend to the welding machines.

On the Richmond Project, for example, seven portable, single-operator, motor-generator welding machines were used. These machines delivered direct current with a working radius of 400 ft. All machines were grouped in one battery for easy supervision on the ground adjacent to the building site.

A new hazard has been added to the worries of the building construction worker. That is the danger of being struck by spatter from a welder's torch high up aloft in the framework. While the danger to life is not great, painful and infectious burns may be incurred. Weld spatter also presents a problem in the finishing of exposed concrete surfaces subjected to this rain of rust stain producing scale.

(a)

(b)

(c)

Fig. 16 Erecting for welded construction

Note use of connectors and absence of angles and gussets

ECONOMIES REALIZED

To summarize, we may expect savings in material wherever welding is applied to structural design, but this does not always mean savings in final cost under present mill and shop conditions.

Certain structural elements such as trusses and plate girders lend themselves admirably to the economies of welded design.

The use of welding in building frames should be a matter for thorough study.[2] If welding is indicated, the entire design must be centered around this premise. The design assumptions and the framing plan must make use of the unique characteristics of welding for tangible results. Continuous construction does this. Acceptance of butt welds at full value in tension has made continuous steel framing as simple as reinforced concrete.

In all-welded design, extra cost of unusual sections and special materials must be weighed against anticipated savings in material.

CONCLUSION

During the past two decades the reasons for using welded construction have been numerous. In some cases the elimination of noise and vibration was important. Speed of erection indicated its use on other projects. Its versatility recommended welding when it was necessary to add on to existing structures. When continuous construction was specified, welding seemed the obvious solution.

Important as these advantages are, the widespread adoption of welding (or any new construction technique) will probably depend on cost. With a tightening economy and keener competition, construction costs must be cut. Savings can be made by reducing material, by cutting shop fabrication or by saving labor at the erection site.

The large material savings realized through welding are of prime importance. The shop fabrication must be made simpler. Processes such as punching and drilling must be reduced or eliminated. Methods to make savings at the erection site must be originated, developed and universally adopted. The fact that they have not been is the result of yesterday's sellers market.

I feel confident that if the fabricating industry is confronted with designs that preclude any but the efficient methods of all-welded construction, the industry will solve its problems of economy in shop and field assembly.

Cutting Maintenance Costs with Aluminum-Bronze Electrodes

Aluminum-bronze electrodes are assuming an important place in overlaying new and worn steel and difficult to weld metals and alloys

by Joseph A. Cunningham

OVERLAYING WORN PARTS

WHERE metal-to-metal contact is involved, hard grades of aluminum-bronze electrodes (160 to 300 Brinell) are rapidly assuming an important place in overlaying new and worn steel parts because they provide low-friction, nonseizing surfaces and wear remarkably well. Further, aluminum-bronze electrodes can be applied to high-carbon, alloy or tool steel without danger of spalling off or cracking the parent metal. Most grades of cast iron and bronze can also be overlayed.

Joseph A. Cunningham is President of Jos. A. Cunningham Equipment, Inc., Philadelphia, Pa.

Presented at Thirtieth Annual Meeting, A.W.S., Cleveland, Ohio, week of Oct. 17, 1949.

Fig. 1 Pump shafts worn (left) and rebuilt (right) at packing location with hard aluminum bronze

Overlays are successful on difficult-to-weld metals, such as large tool steel, medium carbon or cast-iron gears, because bronze inherently possesses a characteristic of penetrating into the pores of the metal and bonding firmly. Also, since aluminum bronze melts at approximately 1950° F., 700° less than steel, it can be applied rapidly without materially affecting the heat treatment in the parent metal and the deposit feathers out as welded and leaves no craters when the arc is broken.

Much of the long wearing characteristics of aluminum bronze, i.e., A.W.S. filler metal specification No. ECuAl-D (250 Brinell) and A.W.S. No. ECuAl-E (300 Brinell) can be attributed to the high polish attained by the bronze as it wears. Excellent life is obtained even when the bronze overlay is working against hardened steel parts due to the nonseizing effect of dissimilar metals working against each other. Bronze overlaid shafts (Fig. 1) operating against pump packing, lasts 3 to 6 times longer than the original shafting which is usually harder than the bronze overlay. It is interesting to note also that packing life is tremendously increased when shafts are overlayed with hard aluminum bronze because bronze wears smoothly and does not pit or corrode. When shafts are to be operated against bronze bearings, bronze overlays are not recommended because the dissimilar metal effect would not be present.

Rebuilding low areas in gear teeth, that would be impractical with other electrodes due to craters and high beads, can be accomplished by the use of aluminum bronze, since the overlay is smooth and

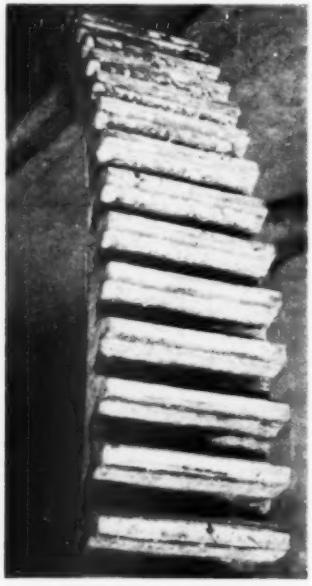


Fig. 2 Tube mill gear segment

A low area, 1 1/4 in. wide, across the center of each tooth was restored with one pass of a 1/4-in. diameter hard aluminum bronze (250 Brinell)

Fig. 3 Clutch pinion on a tube mill feeder

The worn teeth were rebuilt with 3/16-in. hard aluminum bronze. No template was used. The original pattern of the tooth could be seen to the left of the pencil. Arrow indicates clutch surfaces also rebuilt with hard bronze

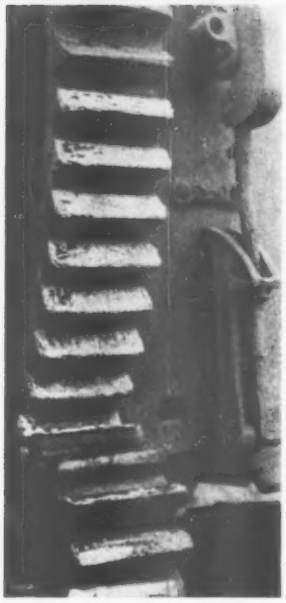


Fig. 4 Cast-iron tumbler gear

The initial pass applied with aluminum-bronze ECuAl-A1 the second pass with ECuAl-D; a similar third pass is to be applied when time permits. The pinion was rebuilt with aluminum-bronze ECuAl-E

blends gradually into the parent metal at the fusion zone (Fig. 2). Also gears that are worn to a sharp edge can be overlayed with a comparatively large electrode without danger of melting through at the edges, see Fig. 3, in which a $^{3}/_{16}$-in. electrode was used, and Fig. 4 where a $^{1}/_{4}$-in. electrode was used. Craters are entirely eliminated and grinding* is usually unnecessary because the bronze surface is evenly contoured and the deposit is not so hard that it would cut into a steel gear. When templates are not used, the deposit is left slightly undersized to prevent binding. Rebuilt gears cause less wear on the mating surface not only because of the dissimilar metal effect, but because rebuilding is bound to improve the contour of the tooth and restore the original rolling action designed in the tooth. This eliminates much of the sliding friction that accompanies worn gears. The resultant low friction, long-wearing surface makes an ideal match against mating steel gears or pinions. When both pinion and gear are overlaid, a harder grade ECuAl-E (300 Brinell) is recommended on the pinion (Fig. 5). When wear is severe due to the presence of abrasives a 400–500 Brinell hard facing that takes a high polish is recommended on the pinion. Pinions should be harder than gears since they contain less teeth and hence are in contact more frequently.

When teeth are worn excessively, copper or concrete templates can be used to acquire the proper contour. See Fig. 5 showing a concrete template and Fig. 6 (*b*) showing a copper template. In Fig. 5 a cement clinker-tube mill pinion was rebuilt with only 12 lb. of $^{3}/_{16}$-in. aluminum-bronze ECuAl-E (300 Brinell) and required only $4^{1}/_{2}$ hr. of welding and $3^{1}/_{2}$ hr. of grinding to finish the job.

In Fig. 6 the large 10 ft 6 in. diameter

* Overlaid aluminum bronze deposits with ECuAl-B and ECuAl-C are readily machinable even on high-carbon steel when deposits are $^{3}/_{16}$ in. thick. ECuAl-D is machinable with high-speed steel tools but tungsten carbide tools are preferred. ECuAl-E is machinable but with considerable difficulty, and is not generally recommended.

Fig. 5 Pinion with concrete template is easily rebuilt to size with aluminum-bronze ECuAl-E

Hand grinding permitted close tolerances. However, many pinions have been successively rebuilt without templates

Fig. 6 (a) Build-up, $^{3}/_{16}$-in. thick on a tube mill gear in a cement mill with aluminum bronze ECuAl-D

Initial build-up with E9025 lime ferritic 90,000 psi. electrode

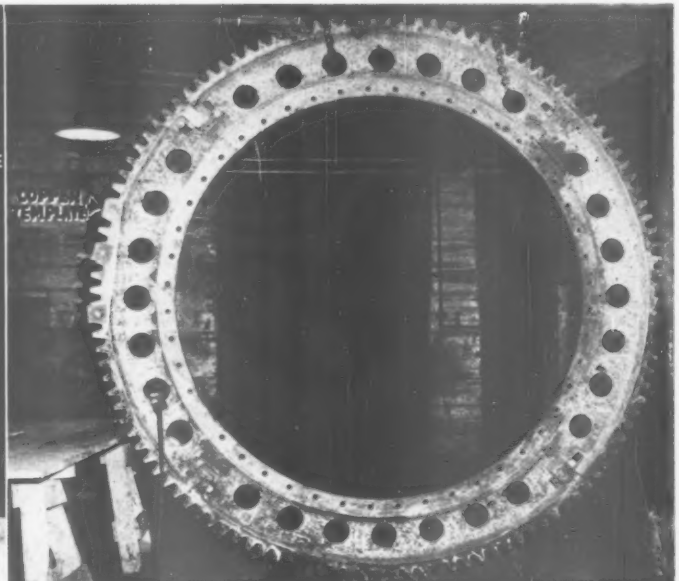


Fig. 6 (b) Side view of tube mill gear showing one half of the copper template covering 9 teeth

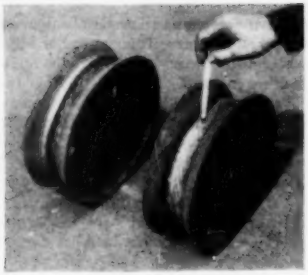


Fig. 7 Cable idlers, both rebuilt with aluminum bronze

The one at the left with the softer grade; the one at the right, with ECuAl-D both give satisfactory life. Note, however, the harder grade has barely worn. Both were in service the same length of time

Fig. 8 Broken cast-iron gear teeth welded with ECuAl-A

The steel studding provides extra support for very heavy compressive forces

Fig. 9 Rack on an overhead crane welded together with Ampco ECuAl-A to eliminate rail end failure and thumping at joints

gear with 120 teeth, each 11 in. across the face, was rebuilt at the cost of $530. It required 225 lb. of 1/4-in. aluminum-bronze ECuAl-D (250 Brinell) in two passes superimposed on a pass consisting of 85 lb. of 1/4-in. 90,000 psi. (E9025) lime ferritic low-alloy steel electrodes. Eighty-two hours of welding time was required to complete the job and no machining or grinding was deemed necessary. The gear after 5 mo. service shows very little wear and has operated quietly from the start. A new gear would have cost $2148 representing a saving of $1718 by rebuilding. Many large gears have been rebuilt without dismantling and without the use of templates. In these instances it is well to apply the same number of passes to each tooth. Frequently one end of the tooth is not worn and this can be used as a guide for size. A light, sheet-metal template is helpful if the outline of the original gear can be obtained. When space permits, weld beads should be applied in a weave four times the diameter of the electrode.

The gear in Fig. 2 is approximately the same size as Fig. 6, but was not worn nearly as mu h. Prior to welding, the gear train became noisy because the pitch of the pinion teeth was not uniform throughout and caused a low spot to wear across the middle of the gear teeth and abnormal wear became apparent at several places on the gear as the error in pitch multiplied. The cost of repairing it was only 1/4 of the price of repairing the gear in Fig. 6. After welding it ran exceptionally quiet against a new tool steel pinion.

The comparatively small clutch pinion in Fig. 3 would have cost approximately $125 to replace because the shaft is hollow and considerable machining would be involved. It was rebuilt for only $5 total cost and required 2 1/2 lb. of 3/16-in. ECuAl-D and 3/4 hr. welding time. No machining or grinding on the overlaid gear teeth was necessary. Worn clutch surfaces, which must be machined after welding, have a tendency to mushroom after being rebuilt with mild steel electrodes. However, they show both increased life and no mushrooming in service after welding with hard aluminum bronze. (See small arrow at the end of the shaft in Fig. 3 for rebuilt clutch surfaces). The ECuAl-D Bronze on the clutch surfaces was machined after welding, although hand grinding would have been satisfactory.

Worn cable idlers are ideal to rebuild with hard aluminum bronze because the deposit wears well and the life of the wire rope is prolonged due to the low friction nonseizing characteristics of the bronze weld (Fig. 7).

Large cast-iron gears can be successfully overlaid also (Fig. 4). However, if more than two layers are required on cast iron, the softer grades of aluminum bronze should be used as the initial build-up.

Many other important uses of hard grades of aluminum bronze include slides and guides, metal forming or drawing dies, valves, cable drums, rockers, slippers, cams, etc.

Where porosity-free welds are required, such as on valve faces, all grades of the coated aluminum-bronze electrodes can be applied advantageously by carbon-arc welding using the electrode with the coating on it. This process usually improves machinability. Frequently the carbon-arc process is used to repair large cast-iron castings.

JOINING AND REPAIRING BROKEN PARTS WITH A SOFTER GRADE ECuAl-A

Since the softer grade of aluminum bronze, ECuAl-A has an unusually high tensile strength (77,000 psi. on bronze)† and excellent ductility (27%) with a comparatively low yield strength (35,000 psi.)‡ it is ideal for welding broken tools, high-carbon steel or cast iron. However, these electrodes are adaptable for other reasons—(*a*) bronze seeps deep into the pores of the parent metal to form an excellent bond, (*b*) it is applied at a low temperature and consequently has little effect on heat-treated components (Fig. 10) and (*c*) resultant low-temperature applications minimize distortion.

A cast-iron gear 9 ft. in diameter with part of the teeth broken out was drilled, tapped and studded with 3/4-in. pins and subsequently welded with 3/16-in. aluminum-bronze ECuAl-A after applying a local preheat of 300° F. (Fig. 8). Each layer was hand peened to relieve contraction stresses and the resultant job dressed with a 9 in. diameter by 3/16-in. thick laminated grinding disk used on a vertical type 6000 rpm air grinder. The deposit

† Physicals are taken from data furnished by a manufacturer. See Table 1.

‡ Comparatively low yield strength allows the residual stresses to be taken up by the weld metal and prevents tearing away at the fusion zone.

Table 1—Aluminum-Bronze Electrode Deposits Comparative Mechanical Properties*

A.W.S.-A.S.T.M. Electrode classification	*Tensile strength, psi. av.*	*Yield strength (0.5% extension under load), psi. av.*	*Elongation in 2 in., av., %*	*Brinell hardness, av. 3000 kg. load*
ECuAl-A	77,000	35,000	27.0	120
ECuAl-B	89,000	47,000	15.0	160
ECuAl-C	90,500	46,000	4.0	200
ECuAl-D	77,000	54,000	1.0	250
ECuAl-E	80,000	69,000	0.5	300

* In matching grade of aluminum bronze.

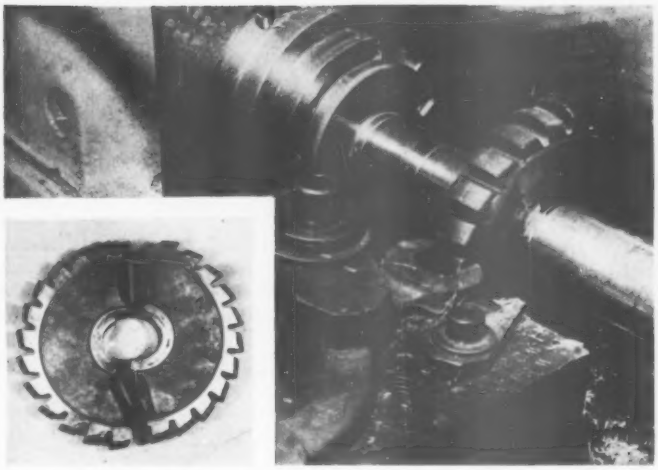


Figure 10 (a)

Fig. 10 (a) Large milling cutter ground prior to welding with aluminum bronze grade ECuAl-A

Figure 10 (b)

Fig. 10 (b) The welded milling cutter is as good as new—no annealing and no subsequent hardening was necessary. Heat treatment was not noticeably affected

was sound and free of porosity. Low-temperature application, ability to penetrate into the pores of the cast iron, high tensile and ductility all contributed to the success of this highly stressed weld.

On a wide-span heavily loaded overhead crane runway in a cement mill, rail ends were repeatedly wearing down and flacking off, necessitating repairs every 2 mo. The fish plates were removed and the webbs and flanges were beveled and welded in place with $^3/_{16}$-in. aluminum-bronze type ECuAl-A. The fish plates were replaced, bolted on again and reinforced with aluminum-bronze welds. The rails were then trimmed off to a depth of $^1/_4$ in. with an acetylene torch, preheated to 500° F., overlaid with $^1/_8$-in. diameter hydrogen free 0.60% carbon electrodes having a Brinell of 350. The joint is still good after 10 mo. service without repairs (Fig. 9).

A large milling cutter, cracked through the center, was veed out (Fig. 10 (*a*)), preheated to 400° F., and welded with $^3/_{32}$-in. aluminum-bronze ECuAl-A (Fig. 10 (*b*)). The low melting point of the bronze allowed welding without destroying the heat treatment in the high-speed steel. (*Note:* High-speed steel is generally drawn at 1000–1100° F. but, even on oil hardening, steel with a draw range of 450° F., the hardness would not be lowered more than approximately one

Fig. 11 A thin-wall gasoline fill pipe for a large truck is metallic arc welded to a heavy cast base without preheat and fit-up is not too good

ECuAl-A bronze electrode, $^1/_8$ in., due to its low melting does not burn through 18-gage tubing

point Rockwell C because the heat of the arc is concentrated in a local area and, further, the speed of travel of the electrode does not permit the heat-treated steel to remain hot long enough to cause any nominal change in structure or hardness). Here again, the high tensile, comparatively low yield, excellent ductility and ability to penetrate into the pores of the parent metal, makes aluminum bronze ideal for the application.

An illustration of the value of low melting point is seen in Fig. 11 where a thin wall fill-pipe is welded to a heavy casting without preheat and without burning through the thin metal. Bronze electrodes are often used in similar instances in welding galvanized stack pipes, ventilating ducts, etc.

Other uses for grade ECuAl-A include welding dissimilar metals such as joining bronze clips, brackets or liners to steel; rebuilding worn bronze parts, fabricating bronze plate, overlaying valve faces and seats.

(*Continued from page 1151*)

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(*Continued on page 1171*)

WELDING METALLURGY—Iron and Steel

The Society has revised the Welding Metallurgy book originally published in 1940. The book has been brought up to date and a wealth of new material added. This book is being reproduced serially in* The Welding Journal. *Copies in attractive imitation leather covers are available at $2.50

by O. H. Henry, G. E. Claussen and G. E. Linnert

Chapter 4
TEMPERATURE CHANGES IN WELDING

Before we can be said to have control over the metal in the weld and in the adjacent heat-affected zone during welding, we must know the temperature reached by every part of the joint and the time at those temperatures. Unusual combinations of temperature and time must be dealt with in welding. The temperature changes during welding are generally wider and more abrupt than in any other metallurgical process. Furthermore, only very limited recourse can be had to the familiar metallurgical operations of working and heat treatment upon which the metallurgist ordinarily relies to place his products in their most satisfactory condition. Nevertheless, a number of astonishing and unpredictable facts have emerged from the study of welds, such as the fine grain size of mild steel weld metal, that have forced us to adopt new concepts especially applicable to welding.

The important facts that we must gain about the temperature changes during the welding of a given metal or alloy are:

1. Rate of Heating.
2. Maximum Temperature.
3. Length of Time at Temperature.
4. Rate of Cooling.

When these facts are known, we can consult the principles of metallurgy to determine the effects of welding on the metal.

HEAT AND TIME IN WELDING

In reviewing this subject, we will see that the rate of heating is dependent upon the intensity of the heat source and the efficiency of heat transfer. The maximum temperature that is attained will be determined by the rate of heat input and the rate of heat loss into the mass of base metal in contact with the weld and the atmosphere surrounding the metal. The length of time at temperature merely depends upon the length of time we maintain an even balance between heat input and heat loss. If the input exceeds the loss, we have not yet attained maximum temperature. On the other hand, if the input is less than the loss we are immediately concerned with cooling rate.

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Generation of Heat

Heat has the effect of raising the temperature. To raise the temperature of 1 pound of water 1° F requires 1 Btu or 252 calories. In making a spot weld in heavy steel plates we may raise 1 pound of steel to its melting point (2700° F) almost instantaneously. The approximate amount of heat required to melt 1 pound of steel is 1 lb. $\times$ 2700° F $\times$ 0.1 = 270 Btu or 70,000 calories (specific heat of steel = 0.1; that is, to raise the temperature of 1 pound of steel 1° F requires only 0.1 Btu). To secure 70,000 calories we need its equivalent 300,000 watt seconds, which is supplied by 10,000 amperes for 10 seconds at 3 volts across the plates to be spot welded.

In practice we find that we need more heat than we calculated to secure the right amount of weld metal. The reason is that once the temperature is raised at one spot in a plate, the temperature rises at all regions in the vicinity according to the physical law of heat conduction. Therefore, the heat of welding must be sufficient not only to melt the metal required for welding, but to raise the temperature in the vicinity of the weld to the extent required by the law of heat conduction. From this it is obvious that the slower the rate of heat input for a welding process, the greater will be the amount of heat required over and above the amount required to melt the metal.

In resistance welding the heat for welding is generated within the metal itself. It is important to remember, however, that the heat is developed at two locations; in the body of the material where the electrical resistivity of the metal determines the amount of heat generated, and at contacting surfaces where the resistivity is affected by many factors including pressure, surface oxides and compounds, surface roughness, and surface cleanliness.

In gas welding, the heat is generated in the flame, the high-temperature molecules of which impart their thermal energy to the metal. Thermal energy arises from the fact that all matter is in chaotic motion. The speed of motion of the individual particles (molecules) of a gas increases with rise in temperature. It happens that energy is the product of mass times square of speed and, furthermore, that the kinetic energy of each molecule is directly proportional to the temperature. The energy of the gas, that is, of the molecules, in a high-temperature welding flame consequently is very high, and is increased by the rotation of the molecules themselves, which adds to the energy of translational motion.

When the flame surrounds the metal, the atoms at the surface of the metal attempt to attain the temperature of the flame, thus establishing equilibrium. As the thermal energy, which is the measure of temperature, increases among the surface atoms, the atoms deeper below the surface attempt to attain the same thermal energy level as the surface atoms and their temperature likewise rises. The law governing the transmission of the energy to change the energy of the atoms is the law of heat conduction.

In arc welding, the metal to be welded is one pole of an electrical circuit, while the electrode is the other pole. By maintaining a suitable gap between the work and the electrode, an arc can be formed to generate heat. Thus the metal to be welded participates in the production of heat, which is not so in torch welding. In arc welding the metal is not the sole source of heat, as it is in resistance welding. The heat developed by the arc is approximately: arc voltage $\times$ arc current $\times$ time the arc burns. For instance, a covered electrode arc at 35 volts, 150 amperes, liberates $35 \times 150 = 5250$ watts every second. In one second the arc therefore develops 1250 calories or 5 Btu (equivalent to melting 0.02 pound of steel in a second). Some of the heat developed by the arc is lost to the air, as the welding operator behind his shield will realize. Tests have shown that about one-fourth the heat developed by the arc is lost to the air (including vaporization of steel) and the electrode. The remaining three-fourths of the heat acts to raise the temperature of the parts to be welded. A similar proportion of the heat from a welding torch doubtless is lost to the air. The heat liberated by a welding flame is the product of volume of combustible gas delivered by the torch and the heat of combustion of a unit volume (cubic feet) of the gas.

Temperature Distribution

We have now taken three common welding processes and shown in each how the welding heat is originated as thermal energy which we measure in units of temperature. We are now in a position to discover what effect the heat exerts on the temperature of the parts to be welded, and also what becomes of the heat in the metal.

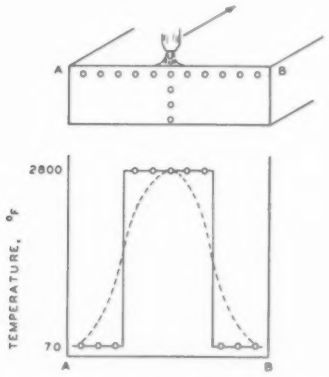

Fig. 12
(Upper) Temperatures are being measured by means of thermocouples at the circles while the arc or torch melts a path across the surface
(Lower) Readings of temperature are recorded along the line of thermocouples *AB*

In Fig. 12 a flame is playing on a metal surface, and we are measuring the temperature at a number of points (line *AB*) just beneath the surface. If there were no such thing as heat conduction, or if the flame were able to bring the surface under the tip of the inner cone instantaneously to the fusion temperature, our pyrometers connected to the points along the line *AB* would indicate the temperature shown by the full lines in the lower part of Fig. 12.

Actually, however, metals are good heat conductors; the atoms in the metal pass heat along rapidly to their neighbors. Besides, the heat to melt the metal cannot be supplied instantaneously by the flame. Heat is a product of amperes, volts, and, all-important, time, as we have seen. For these reasons our pyrometer readings along *AB* will take the form shown by the dotted line in Fig. 12. The dotted curve takes account of time and heat conduction, whose effects were neglected in the full lines. Curves of the type shown in Fig. 12 are called temperature-distribution curves.

In arc and gas welding, we can assume for the moment that a point on the scarves receives little heat until the arc or torch is played upon it. As soon as the base metal has been raised to the proper temperature, and the filler metal, if any, has been deposited, the arc or torch is moved on. We are not too far wrong in assuming again that the point in question receives little more heat from the retreating flame. The temperature distribution at the point in question, when the flame is playing upon it, is shown by the straight line *A* in Fig. 13—the instantaneous-heat-source type of distribution.

When the flame is moved away, the heat is conducted from the weld into the plate. So little heat usually is lost to the surrounding atmosphere that it can be neglected. Curve *B* in Fig. 13 shows the temperature distribution a short time (let us say 1 second) after the flame has moved on. The temperature of the weld has fallen while the temperature of the plate near the weld is rising. After another second, curve *C*, the weld has cooled still further; the plate is still rising in temperature. Curve *D* represents a later stage; the weld has reached quite a low temperature, and some of the heated zone of the plate (called the heat-affected zone) nearest the weld has also reached the maximum temperature and is cooling. Parts of the plate at a considerable distance from the weld continue to rise in temperature, though only to a small extent.

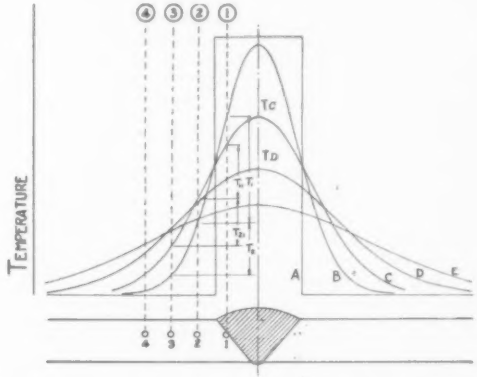

Fig. 13—Temperatures at All Points in the Vicinity of a Weld at Five Different Times. The Curves Were Calculated by Carslaw for an Instantaneous Source of Heat

Eventually, the temperature distribution curve will become horizontal. The temperature at which the distribution becomes horizontal depends upon the size of the part we are welding. If the part is thin and narrow, it may be uniformly red-hot soon after the flame has passed by.

In the majority of welding applications, however, the masses are large and the temperature becomes equalized throughout the part only after it has reached room temperature once more.

Temper Colors

A simple approximate method for comparing the temperature distribution under different welding conditions is to observe the temper colors on the plates after the weld joint has cooled. The familiar temper colors arise from the different thicknesses of iron oxide films on the surface of the steel; the films and their accompanying colors will not form in a non-oxidizing atmosphere, and therefore are not related directly to changes in the structure of the steel.

To permit temper colors to form, the plates should be sand blasted before welding. The brown temper color changes to purple at 525–575° F. Consequently, any part of the plate that is in the zone in which the brown temper color is merging into the purple reached a maximum temperature of 525–575° F during welding. For a given plate thickness the weld in which the brown-purple transition is closest to the edges of the weld has cooled the fastest.

The brown-purple boundary may be about 3 inches from an oxy-acetylene weld in $^1/_2$-inch steel plate, but may be only 1 inch from an arc weld in the same plate. Loose statements of this sort are likely to be misleading. For example, if we deposited a series of unusually thin beads in making the gas weld, the temper colors would be closer to the weld than in an arc weld made at high current and slow speed. We must take the rate of heat input into account in stating the type of welding that is being done.

TEMPERATURE GRADIENT AND COOLING RATE

At this point we are ready to define temperature gradient—a term we shall meet again in the discussion of shrinkage stresses in welding. Temperature gradient is nothing more than the difference in temperature between two points a unit distance apart. For example, if we are arc welding two steel plates and the temperature 1 inch away from the weld is 200° F, the temperature gradient is approximately 2800 — 200 = 2600° F per inch. The temperature gradient is by no means constant at any moment during welding. In Fig. 13 points *1*, *2*, and *3* are 1 inch apart, let us say. At the time corresponding to curve *B*, the temperature gradient is T_1° F per inch between points *1* and *2*. Further, at the time corresponding to curve *C*, the temperature gradient between *1* and *2* has decreased to T_{11}° F per inch. Also between *2* and *3* the gradient has decreased to T_{21}° F per inch. The steeper the temperature distribution curve, the higher is the gradient, which is merely a statement of part of the law of heat conduction.

A more important characteristic of the temperature distribution is the cooling rate. Referring again to Fig. 13, we see that the temperature of the center of the weld fell from T_c to T_d in the second between the recording of curves *C* and *D*. The weld therefore cooled at the rate of $T_c - T_d$° per second. During the next second the temperature of the weld did not fall so much; that is, the rate of cooling was retarded.

To understand the basic rules about cooling rate, we draw Fig. 14, which represents the same pyrometer readings as in Fig. 13. Let us study curve *1*, which shows the temperature of point *1* after the flame has brought the point to the molten state, and has passed on. Allowed to cool freely, point *1* at first cools rapidly while the temperature gradient is high. As temperatures become equalized and the temperature gradients become smaller, the temperature falls less rapidly; that is, cooling rates decrease. Between the first and second instants after the flame has passed, the temperature fell, let us say, 900° F. The cooling rate therefore was 900° F per second. Between the second and third instants, the fall was less, only 400° F, and the cooling rate therefore was 400° F per second.

We might argue that, since the temperature fell 1300° F between the first and third instants, the average cooling rate was 650° F. To avoid this complication, we speak of average and instantaneous cooling rates. The average rate is calculated from the temperature drop during a stated period of time. The instantaneous rate, on the other hand, is computed from the time occupied in cooling through a stated interval of temperature; the smaller the interval the better for welding purposes. For example, the weld metal might fall 1° in 0.001 second very shortly after the start of cooling (instantaneous rate of cooling is equal to 1000° per second), that is, at about 2800° F, whereas a minute or so after the flame had passed, the time occupied in falling 1° might be 1 second (instantaneous rate of cooling is equal to 1° per second) at, let us say, 600° F. Average rates are likely to be misleading, whereas, if we know the instantaneous rate of cooling at each temperature during cooling, we cannot ask for more.

Leaving curve *1* of Fig. 14, we perceive that the temperature at point *2* very rapidly rises, as heat is conducted to it from the weld metal. The rapid rate of heating is a characteristic of nearly all welding processes. The heating is most rapid, of course, at the start of the weld when the flame or arc strikes cold metal. Yet it is extremely rare, and only when accompanied by rapid cooling rates and in the welding of brittle metals, such as white cast iron that difficulties occur in welding due to too rapid heating. The reason is clear. The instant the average metal is heated to a red heat it loses its rigidity. The metal quickly reaches its maximum temperature, which is

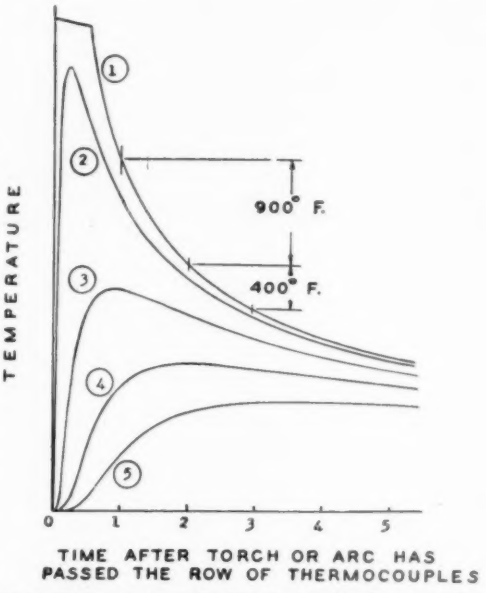

Fig. 14—The Temperatures in Fig. 13 Are Replotted as a Function of Time for Four Different Distances

a little less than the temperature of the weld metal at that moment. Cooling then sets in, following the same law of heat conduction that is obeyed by the weld metal. Observe, however, that the cooling rate at any temperature always is slower at point *2* than in the weld metal (point *1*). Cooling rates became slower the farther we move from the weld, as shown by curves *3* and *4*. Other things being equal, the higher the maximum temperature reached by a point in welding the higher the instantaneous cooling rate will be after cooling has begun.

Before passing from this theoretical discussion to a consideration of temperature distributions and cooling rates in different welds, it should be mentioned that the curves upon which Figs. 13 and 14 ars based were calculated long before anyone had made temperature measurements of welds during welding. Yet the general theoretical basis of these diagrams has been found to yield results when applied to some types of welded joints, which agree within 5 per cent or so with precise experimental measurements.

Rate of Heat Input

The rate of heat input in welding may be expressed in the following way. The arc power in watts (amperes × arc volts) is divided by the speed of travel of the electrode. For example, the rate of heat input of an arc at 30 volts, 200 amperes, welding at 6 inches per minute is 1000 watt minutes per inch of weld, only three-fourths of the heat reaching the steel. It will make some difference in temperature distributions and cooling rates, however, if the weld is of type *A*, Fig. 15, rather than Type *C*. Type *A* corresponds with the high bead deposited by a bare electrode, medium arc length. Type *C* corresponds with an exceptionally fluid weld metal from a covered electrode.

It becomes apparent that to express the rate of heat input properly we must base it not only on unit length of weld, but on size (height and width) of bead. If $L_a = {}^1/_4$ inch and $L_c = {}^1/_2$ inch, the heat inputs in the example (based on an input of 1000 watt minutes per inch of weld) become 4000 and 2000 heat units (watt minutes) per inch of weld and per inch of bead. Comparing a bare electrode with a covered electrode at the same rate of heat input based on length and width of bead, we would be wise to remember that the bead from the covered electrode may be covered with a thick layer of slag. The slag acts as an insulating blanket over the weld, preventing the normal loss of heat to the air. As a result, cooling rates will be slower in the covered weld bead than in the bare.

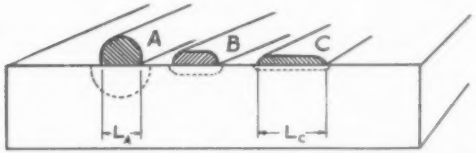

Fig. 15—Three Shapes of Weld Beads Illustrating the Higher Temperature Gradients and Cooling Rates Near C Than Near A

Owing to the difference in mass of weld metal at the edge of the bead compared with the center, the cooling rates will vary along L_a

For practical purposes the rate of heat input is expressed simply by the current. As we increase the current, holding the welding speed constant, the cooling rates fall. This fact is illustrated in Fig. 16. In the same way if we change to a larger tip in gas welding without increasing the speed of welding, we melt more metal and the brown-purple boundary is farther from the weld.

Mass

It is a common experience to observe how far the temper colors spread around a weld in a thin sheet, while if the torch is moved at the same rate over a ${}^3/_4$-inch plate, temper colors scarcely appear under the flame. The explanation is that the sheet is backed up by air, which conducts heat only one-thousandth as rapidly as steel, whereas the surface layers of the plate are backed up by more steel, which is an excellent conductor cmopared with air. The heat supplied to the plate goes to raise the temperature of a hemispherical mass of steel ${}^3/_4$ inch in

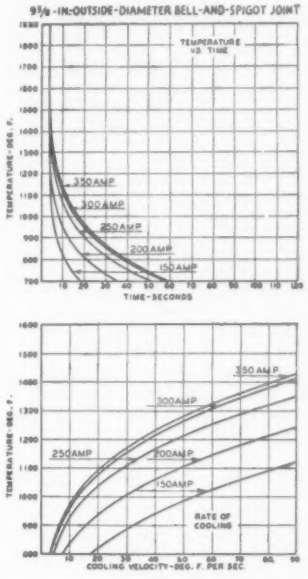

Fig. 16

(Upper) Cooling curves of the end of a weld in oil well casing 0.450-inch wall, at five current settings. Two welding operators deposited four beads with 30-second interval between beads. (Hodell) (Lower) The instantaneous rates of cooling are derived from the upper curves. (Hodell)

radius as shown in Fig. 17. The same amount of heat supplied to the sheet heats the same amount of steel (to the same average temperature). The same temper colors will be found 10 times as far from the torch in the sheet as in the plate, as the very approximate calculations suggest.

Some experimental results on the effect of plate thickness are given in Fig. 18. After 1 minute the unmelted metal close to the bead on the ${}^1/_4$-inch plate has cooled to 600° F, whereas after the same lapse of time the corresponding point in the plate 1 inch thick has reached 200° F. The significance of the difference between 200° and 600° F will be obvious to anyone familiar with the term *martensite* and will be explained in a later chapter.

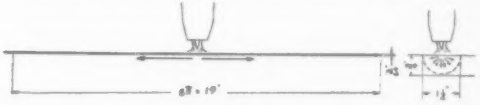

Fig. 17—Assuming Equal Size of Flame and No Loss of Heat to Air or Backing, the Heated Area Is Many Times Larger for the Thin Plate Than for the Thick

Heat losses to air and backing are larger for sheet than for plate, and welding speeds usually are higher for sheet

Instantaneous cooling rates have been calculated from the cooling curves in Fig. 18 and are listed in the tabulation below:

Instantaneous Cooling Rates for Bead-on-Plate Welds

Temperature, ° F	Cooling Rates in ° F per Second ¼-Inch Plate	½-Inch Plate	1-Inch Plate
1400	41	108	180
1000	22	90	152
800	11	40	58
600	4	18	34
450	1.2	..	..
400	..	6	14
300	..	1.3	8.4
200	..	0	0.7

Even with the same plate thickness we can change the mass of metal around the weld bead by depositing the bead on the edge of a plate or in the angle between two plates as shown in Fig. 19. It has been found that for the same welding speed the brown-purplle boundary can be made to stop at the same distance from the edge bead as from the fillet bead by using one-third as much current on the edge as on the fillet. In other words, cooling rates will be the same when the fillet is given three times the rate of heat input. The conclusions we reached in the section on *Rate of Heat Input* are applicable, therefore, only when the mass of metal around the weld is the same for all welds. Mass effect may be expressed quantitatively by expressing the rate of heat input as heat per unit thickness. Actually, it is the metal within a 3-inch radius of the weld that affects the cooling gradient of the weld joint through the important temperature ranges.

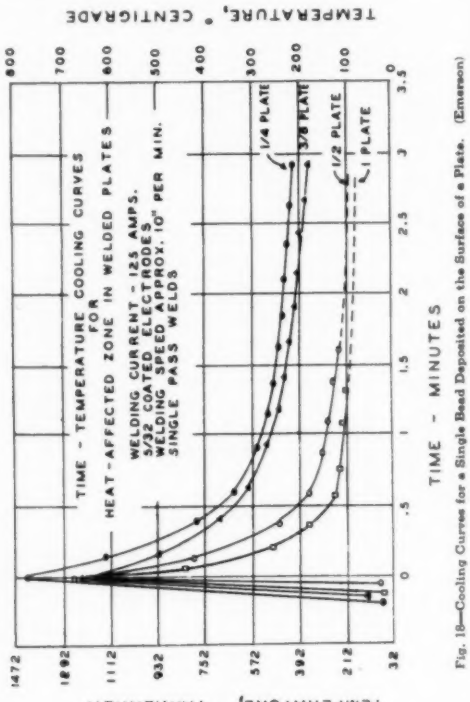

Fig. 18—Cooling Curves for a Single Bead Deposited on the Surface of a Plate. (Emerson)

The heat supplied to the edge bead in Fig. 19 can flow only in one direction, whereas the heat in the fillet can flow into both plates. The outlook expressed in Fig. 17 should be applied to Fig. 19. To be strictly comparable, the area of contact of the bead with the base metal must be the same in both types of weld. Usually the area in contact is higher for a fillet weld than for an edge bead deposited at the same speed and current. For this reason, among others, the cooling rates and dangers from cracking are pronounced in fillet welds. For a given throat size, different shapes of fillets differ widely in contact area. For instance, a convex fillet, Fig. 19, deposited by a bare electrode (short arc) has a low contact area.

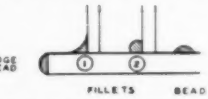

Fig. 19—Shape of Bead, Area of Contact with Plate, and Mass of Surrounding Metal Affect Cooling Rates

From the standpoint of cooling rates the edge weld may be imagined as one-half of a butt weld. Consequently, the temper colors are the same at the same distance from a butt weld as from a fillet weld made with 50 per cent higher current. (Wilkinson)

It will cool slowly compared with the concave fillet *1* which is in contact with base metal over a wide area. A bead deposited at the root of a V-butt weld resembles a fillet bead from the standpoint of temperature distribution and cooling rates. The last bead deposited in a twenty-layer butt weld acts instead like a surface bead.

Will the end of a weld cool at a faster rate than the beginning? It is largely a question of mass. If the weld is made from the center of the plate toward an edge, the end of the weld at the edge will cool more slowly than the beginning. On the other hand, if the weld is made toward a corner, where several members intersect, the chilling action of the mass of metal at the cluster will cause the end of the weld to cool at a higher rate than the beginning.

Preheating

Preheating procedure involves welding on plates that have been heated to an elevated temperature, and reduces the cooling rate in a given type of weld by lowering the temperature gradient. Instead of the total drop in temperature of 2730° F, from 2800° to 70° F, that a weld made in plates at room temperature must undergo, the temperature of a weld in plates preheated to 600° F drops only 2200° F. Cooling rates are reduced particularly at the lower temperatures, such as 1300° to 1000° F. In multiple-bead welds, the succeeding beads may be deposited on metal that has been preheated by the preceding beads. The more rapidly the beads are deposited on each other, the higher is the preheat temperature. Needless to say, the first and most important bead is deposited on cold steel, unless preheating procedure is adopted. Since preheating retards the flow of heat away from a weld, the weld metal and slag may be more fluid on preheated metal than on cold—a matter that may be important in judging the welding qualities of an electrode, especially in vertical welding.

Should it be necessary to weld on steel that is below room temperature, the cooling rates will be unusually high, particularly in the dangerous ranges below 1300° F. It will be pointed out in a later section that rapid cooling in the vicinity of 400° or 600° F may crack welds in some high-strength steels. Welding these steels at unusually low temperatures is risky, because high rates of cooling through the dangerous range are encouraged by the high-temperature gradient. Preheating above the dangerous range, of course, avoids the risks. The temper colors spread to a greater distance around the preheated welds

than the welds made at room temperature. In multiple-bead welding, the depth of grain refining action of the succeeding bead on the preceding bead is greater if the second bead is deposited at once, than if long intervals of time elapse between beads.

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Resistance Brazing of Heat Exchanger

by G. C. Farrington

THE assembly, by silver brazing, of a heat-exchanger unit consisting of steel tubing, internal baffles of stainless steel and external fins of copper (Figs. 1 and 2) was accomplished on standard resistance welding equipment. The process used was resistance brazing. In resistance brazing, heat is generated by the resistance of the parts to the passage of current through the parts. Other methods, such as furnace brazing and torch brazing, were considered but were not used for various reasons. For example, in furnace brazing it would be required to place the 30-in. assembly upright in the furnace to obtain proper flow of the brazing alloy. Production requirements did not warrant purchasing of a large furnace for the job.

Circular, copper alloy clamping electrodes were designed to clamp the ends of the steel tube. The electrodes were attached to an R.W.M.A. Size 2 press welder of 150 kva. capacity. One of the clamping electrodes was attached to the upper platen of the machine and the other electrode was attached to the lower platen with large flexible copper cables. The flexible cable was necessary to provide spacing for the 30-in. high assembly and also to allow for expansion of the assembly as it was heated. Thus, the assembly was held in a vertical position for the brazing process.

The baffles were formed with a very slight taper so that a press fit resulted around the bottom circumference when it was inserted in the tube. The baffles were liberally fluxed and pressed in position in the tube. A silver brazing alloy ring (Fig. 3) was preplaced with each baffle. The fins and outside surface of the tube were fluxed and the fins were stacked in position with a silver brazing ring preplaced for each fin (Fig. 4). The assembly was then clamped in the electrodes for the resistance brazing process.

The first trial of the process illustrated that sufficient heat was generated in the steel tubing by the flow of current to bring the assembly to brazing temperature. However, it was observed that the ends of the assembly reached brazing temperature before the center section. This probably occurred because of the dispersal of heat by the copper fins and possibly because part of the electric current shunted through the base of the copper fins. Air jets were arranged to carry away the excess heat at the ends so that the entire assembly heated evenly.

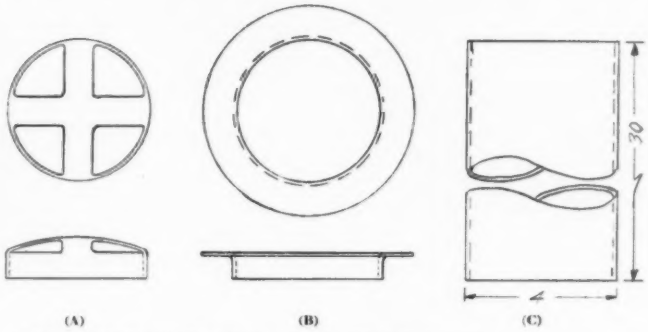
The approximate machine settings and welding values required to produce a satisfactory assembly were as follows:

Open-circuit secondary voltage—11.6
Secondary current—16,500 amp.
Heat time—52 sec.

It is to be noted that there is no value given for electrode force. The electrical circuit to the solenoid valve controlling the air cylinder of the welding machine was opened, no pressure or vertical movement of electrodes being required in this process.

Physical tests of the brazed assembly proved this to be a good application of "resistance brazing" and it is probable that many similar applications can be found.

G. C. Farrington is Welding Engineer, Easy Washing Machine Corp., Syracuse, N. Y.



(A) Internal baffle—14-gage stainless steel; 14 required per assembly
(B) External fin of 16-gage copper; 104 required per assembly
(C) S.A.E. 1020 steel tube—16-gage wall; one required

Fig. 1 Component parts of heat exchanger

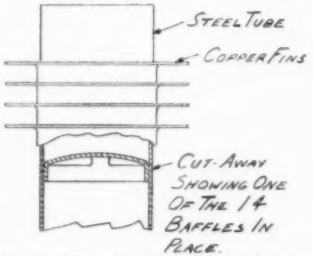


Fig. 2 The assembled heat exchanger

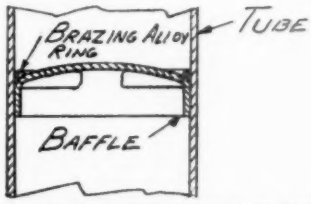


Fig. 3 Baffle and brazing alloy ring in place

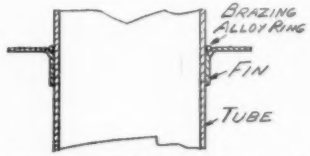


Fig. 4 Fin and brazing alloy ring in place

How Giant-Size Aluminum Trays Were Fabricated

IN THE egg-dehydrating industry, large numbers of trays are needed and the procurement, maintenance and cleansing of these are constant problems. Because of chemical conditions, galvanized iron trays, which have been generally used in the past, are especially subject to corrosion, so that replacement has to be faced almost yearly. A national egg-dehydrating company found that one of its southern plants required complete replacement of trays: 132 hot-water trays, each 22 ft. long, 49.5 in. wide and 6 in. deep; also 600 smaller albumin drying trays and 112 laboratory trays for control. Specifications were severe. Not only must the trays be strong, water-tight and without distortion but, because of being used in the manufacture of a foodstuff, the welds have to be quite smooth and free from all pinholes and irregularities where bacteria might lodge and contam inate the food.

Aluminum was the material chosen for the trays, and a Texas metal shop undertook the fabrication. The giant-size, hot-water trays were an especially interesting problem, and this account of the method devised to make them is presented for the benefit of other shops with similar problems. In this case, stock aluminum sheets could not be obtained, either in 22 ft. lengths or in 49.5 in. widths, so that four smaller sheets had to be joined together. The solution of this problem was an ingenious one.

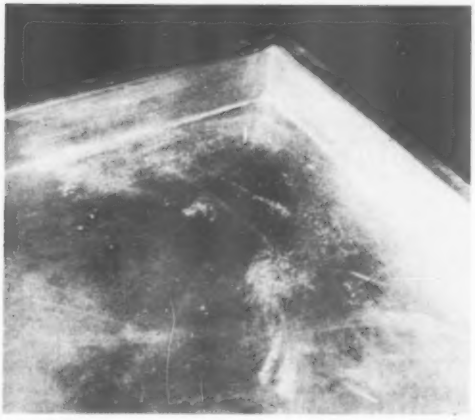


Fig. 1 A close-up of a corner of an aluminum dehydrating tray

Note the smoothness of the weld and the rounded effect at the bottom, which prevents bacteria or dirt from accumulating

Photographs and data furnished through courtesy of Eutectic Welding Alloys Corp., 40 Worth St., New York 13, N. Y

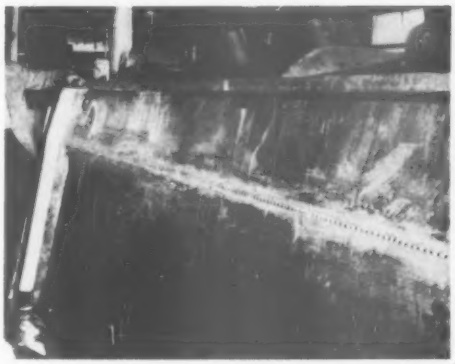


Fig. 2 Large hot-water aluminum trays riveted and joint sealed

Notice length of sheet free of distortion. Corners were welded with thin flowing high-tensile alloy for aluminum welding

The trays were made up in the shop in halves. After the corners had been made using an alloy rod with high corrosion resistance, close color match to the base metal and a tensile strength of 30,000 psi., in each quarter, two quarters were riveted together to make the half, the joined edges being permanently bonded and sealed with a thin-flowing alloy rod which readily and firmly bonds to aluminum at the remarkably low temperature of 350 to 400° F., but nevertheless has a shear strength of 6000 psi. These finished halves were then hauled to the egg-dehydrating plant, where they were set up in position, and the final joining weld made. As said above, 132 such trays were thus fabricated, in length 22 ft.; and not one showed any signs of distortion or warping. No after-finishing was required, and the flux was removed by simple brushing with warm soapy water.

All welds were clean, smooth and absolutely free from pinholes or other irregularities. Figure 1, reproduced from an unretouched photograph, exhibits clearly the extraordinary smoothness and the beautifully curved surface of the welds on these trays, even at the apex of the corners. Figure 2 shows one of the giant-size halves before being set up. Computation proved that, for the entire set of trays, well over a mile of welding was done—and the whole of it by a girl welder who had had only five months' experience when she began this job. Working against time to meet a deadline, she easily maintained a speed of 12 ft. in 20 min., and she had not a single failure with any tray.

How to Make Adjustable Table Legs

WELDING tables, shop tables, jigs and other pieces of equipment must be leveled up occasionally. Here is a simple cap-screw type leveling device that can be put on your shop tables in a few minutes with your oxy-acetylene blowpipe.

For tubular legs, braze weld one nut to each leg of the table as shown in Fig. 1. The other nut locks the cap-screw tightly in position.

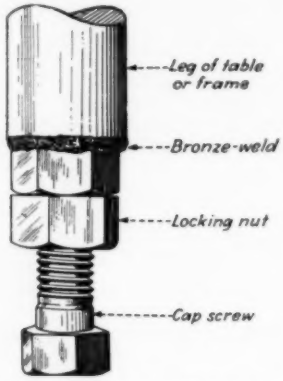


Fig. 1 Just braze weld a nut to the table leg to make this adjustable device

Figure 2 shows a slightly different design that can be used when the legs are made from pieces of angle iron. Braze weld one nut securely to the inside corner of each leg. Then braze weld another nut to the middle of the cap-screw. Fit your wrench on this nut to raise or lower the leg. If desired, a third nut on each bolt can be used as a lock-nut when the table has been adjusted perfectly level.

When you do oxy-acetylene shape cutting, the table must be level to get accurate cuts. As shown in Fig. 3, the leveling device keeps the table for a portable shape-cutting machine level at all times.

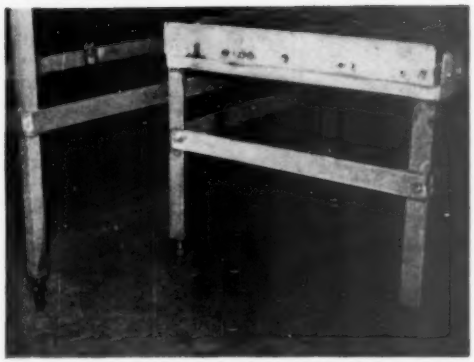


Fig. 2 Here is a similar device for heavy equipment. One nut is welded to the inside of the angle iron. The other nut is also welded to the cap-screw

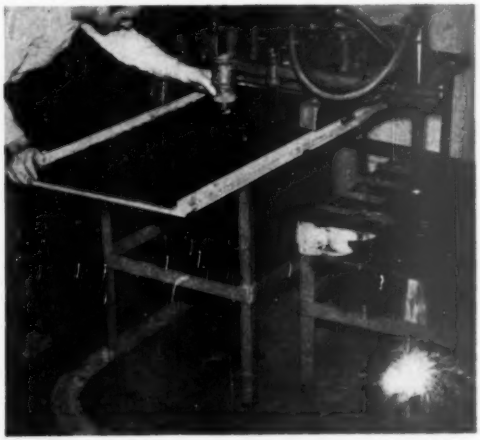


Fig. 3 The table must be level to do accurate shape cutting. Here the leveling device helps the machine operator do a precision cutting job

All photos are courtesy of The Linde Air Products Co.

Production Doubled with Elevating Positioner

BY USING a positioner mounted on a quick-acting elevator, a gland ring was welded, top and bottom, to a pump-liner shell without removing it from the positioner and without changing the level of the "Unionmelt" welding head. The fixture, consisting of a standard welding positioner mounted on an air piston, was designed and built for their own use by engineers at Gardner Denver Co., in Quincy, Ill.

The pump liner assembly is a tubular shell with a fairly thick ring pressed onto one end. The shells are

Fig. 1 Elevator lowers positioner below floor level to make first weld

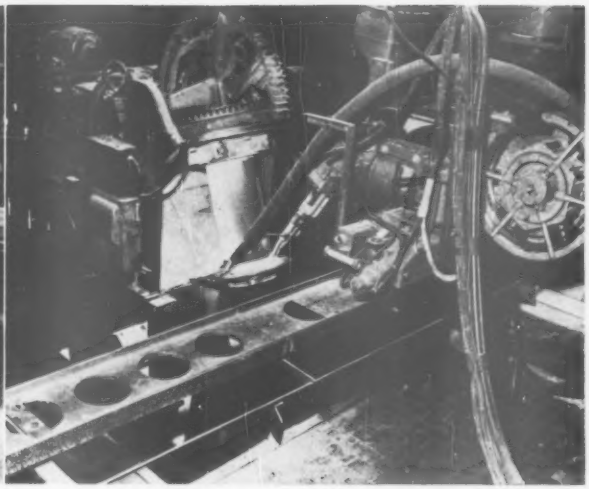


Fig. 2 Elevator raises positioner and compensates for change in level when piece is turned 180°

made of alloy steel tube, $8^3/_4$ in. in diameter and 26 in. in length. The gland ring, $1^1/_2$ in. wide and about $^7/_8$ in. thick, is welded to the shell about 2 in. back from one end. The inner edges of the ring are machined to provide welding vees on top and bottom. Each weld is about 28 in. in length and is made by the Unionmelt welding machine in $2^1/_2$ min.

The liner assembly is clamped to the face plate of the positioner. A sheet metal collar fastened around the gland ring supports the Unionmelt composition which covers the welding zone. The operator opens the air valve and lowers the positioner into a well beneath the floor level as shown in Fig. 1. This brings the top of the gland ring even with the welding nozzle. The carriage is then moved into place and the positioner turns the part at the proper speed while the first weld is made.

It takes scarcely a minute to move the welding head clear of the assembly, elevate the positioner and turn the face plate and piece upside down. This brings the bottom of the gland ring into the downhand position and at the proper elevation for the second weld as shown in Fig. 2.

When the liner assembly was welded by hand, the best production that could be expected was about two units per hour. Using this special positioner and a Unionmelt machine, production was easily boosted to four units per hour.

Repairing Radiators

by W. F. Ruehl

THE air-acetylene flame is a convenient, economical source of heat when you need a low-temperature flame for soft soldering and some heating jobs. Leaky radiators, connections on terminals and rewiring jobs are easy to solder with the air-acetylene torch. Many other soldered repair jobs can also be done on trucks, tractors and automobile parts, because the heat is so easy to control and the torch so easy to use.

W. F. Ruehl is Process Service Representative, The Linde Air Products Co., Baltimore, Md.

This is how one shop repaired a leaky tractor radiator. You should be able to make repairs on similar parts by following the same method. Remember to be careful when you work near materials that catch fire from an open flame, heat or sparks.

The photographs show a solder repair at the hose tube. Usually, this has a flange riveted in place. The solder is used to add strength and make the joint water tight. To do a good job, the solder must creep or sweat between the parts. Clean the metal around the leak with a steel wire brush, knife or file until the metal is bright and shiny. Cleaning is an important step because solder will not stick to metal that is greasy, tarnished, dirty or coated with oxides. Now apply flux to the clean surfaces. Any good commercial paste or

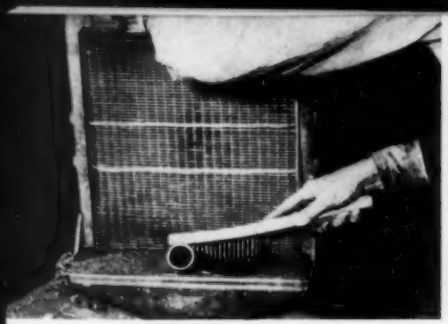


Fig. 1 The first step in repairing a leaky radiator is to clean the metal thoroughly around the leak

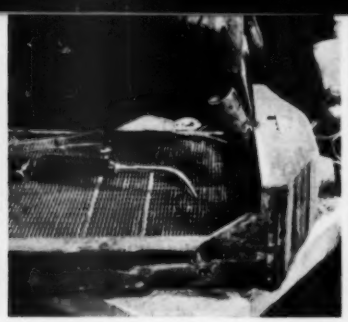


Fig. 2 Apply a good commercial flux—either paste or liquid—to the cleaned surfaces

Fig. 3 Heat the leaky spot but do not let the flame touch the metal. Apply the solder until the spot is covered

liquid flux will do. Light your air-acetylene torch and play the flame over the fluxed area but do not actually touch it to the metal. Heat the metal for a few seconds, then withdraw the flame and touch the solder to the heated area. The solder will melt and flow over the surface when the metal is hot enough to begin work. If it does not run properly, heat the metal a little bit more and try it again.

When the solder flows smoothly, rub the end of the wire gently over the hot metal surface and you will melt enough solder so that it flows over and around the leaky spot and creeps down between the parts. When the solder is thoroughly melted and spread out evenly, let it cool. If the solder has not spread out evenly, wipe it with a damp cloth and spread a little flux around the hole. Heat again, with the flame, to spread and smooth out the solder. When the job is finished, clean the surface well with a damp cloth to remove any flux.

Of course, you will want to test the repaired part before you put the radiator back into place. If the leak has not been completely closed up, repeat the job and melt more solder onto the leaky spot.

This article deals only with soldering in external places. However, many radiator leaks are in the core.

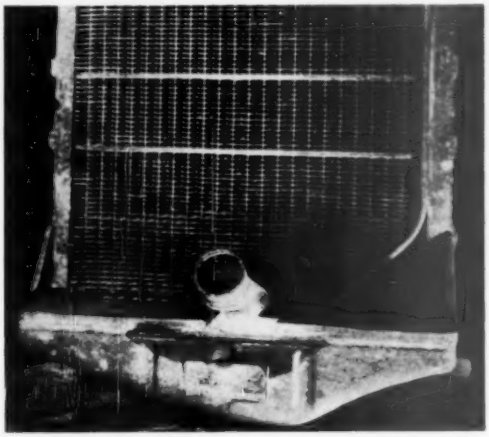


Fig. 4 If the repaired spot is not smooth, add more flux and reheat the solder

To solder them you need considerable experience and practice. If you overheat the core you will cause other leaks.

Welded Letters Can Make a Profitable Side Line

THE letters shown in the illustration, made by Engel-Craft Metal Products Co., Inc. of New York, are formed from $1^{1}/_{4}$- × 6- × $^{3}/_{8}$-in. 24 ST aluminum.

The operator is using a long-flame type tip with a Size 4 No. 98 tip. He is welding with $^{1}/_{8}$-in. diameter No. 25 drawn aluminum rod and Napolitan No. 42 flux.

In the case of letters such as "E" where the elements are perpendicular to each other, the parts to be welded are left with square edges. With letters such as "W" it is merely necessary to grind the edges so they fit at the correct angle before welding. The welds are then ground and the letters buffed.

This particular welding job opens up many interesting possibilities for every welding shop. Raised letters can be attached to the outside of stores as signs or to apartments and houses. Attached to a frame, they are widely used as yard signs for private homes. In short, they can be made into a profitable side line.

Data and Photo Courtesy Air Reduction Sales Co.
Figure 1

How to Do Steel Welding

◗ *Hints for welding steel $^1/_8$ in. or thicker*

by C. H. Wanamaker

WHEN a part will be used at a temperature higher than 500° F. it is best to make the repair by fusion welding. Fusion welding is also the best method if the part will receive a pounding wear, or if the weld must match the color of the original part. When the part is steel—casting, sheet, plate or pipe—steel welding rod is used.

Figure 1 shows a portable welding table that is easy to make and useful in any shop. The angle iron probably is in your shop now. But a $^1/_4$-in. steel plate 30 in. by 28 in. may not be easy to get. You can weld several small pieces to make the table top. You will want to do the welding with steel rod because the top will take a lot of heat and pounding. Here is how to do the welding.

Clean the edges of the steel with a wire brush and remove oil, grease, rust and scale. For steel that is $^3/_{16}$ in. or thicker, it is best to bevel the edges as shown in Fig. 2. The bevels can be made with your cutting blowpipe or by grinding, chipping, or machining. Make the angle between the beveled surfaces 60 to 90°.

After beveling, space the edges for welding. Leave a $^1/_8$-in. space at the start of the weld. At the finishing end of the weld the spacing should be $^3/_{16}$ to $^1/_4$ in. for each foot of the weld. This allows the metal to expand and contract during welding.

MAKING TACK WELDS

The first step is to make tack welds at each end of the welding vee. To make the first tack weld, hold the blowpipe so that there is an angle of about 60° between the blowpipe and the steel plate. Heat the metal for about $1^1/_2$ in. along the vee until it starts to turn red. Now direct the flame at the very end of the vee and get the heat down to the bottom of the vee. At the same time heat the end of the rod in the flame.

The steel will turn from dark to light red, then to

C. H. Wanamaker is Process Service Representative, The Linde Air Products Co., New York, N. Y.

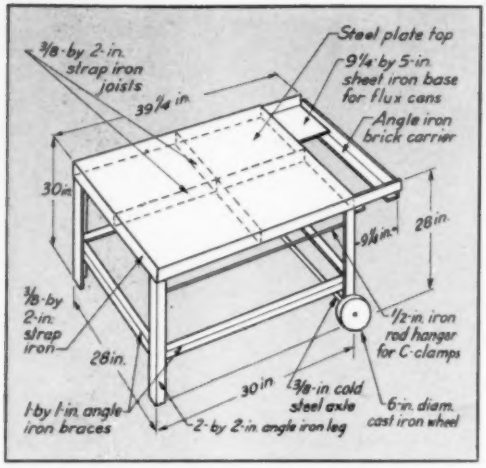


Fig. 1 The top for this table should be ¼-in. steel. Weld several small pieces to get the right size

white before it melts. When the metal on the sides of the bevel starts to melt, add molten metal from the hot welding rod. You will form a molten puddle about the size of a nickel. When the weld is about ½ or ⅔ the thickness of the plate, stop welding and let it cool.

If the weld will be about 12 in. long make a tack weld at the other end. The greater spacing at this end may give you a little trouble in bridging the gap with the metal. Try making a puddle on each side of the vee. Just as the puddles form, direct the flame more on one puddle and add molten metal from the welding rod. As soon as the puddle gets about as large as you think you can control, quickly shift the flame to the other side of the vee and add metal to this puddle. If you work this way, each puddle gets a chance to cool to a plastic state and small ledges will be built out. Soon you will be able to bridge between the two puddles to form one. When one puddle forms, build up the weld to about the same size as the first tack weld. Then stop welding and let the weld puddle cool.

When the weld is more than 12 in. long, the edges will be far apart when spaced 1/16 to ⅛ in. for each foot of weld. You must control the contraction of the edges or

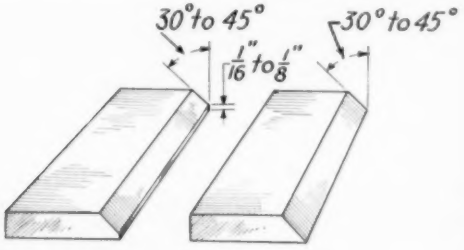


Fig. 2 For steel over 3/16 in. thick, bevel the edges like this. The square nose is best

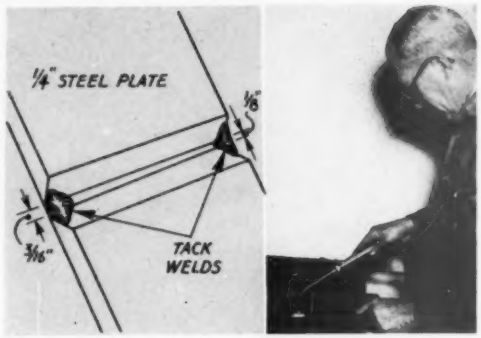


Fig. 3 Line up two pieces of plate so that beveled edges form a vee. Space and make tack welds as shown

they will butt tight or overlap before you finish the weld. An H-clamp 10 to 12 in. ahead of the starting point will keep the proper spacing. When the weld is 4 to 6 in. away move the clamp ahead.

MAKING A FINAL WELD

As soon as the second tack weld has cooled down to a black heat, you are ready to start the final weld. Start the weld at the end that has the narrow spacing and work from right to left. Before welding, raise the other end of the plate about ½ in. above the table, by placing a piece of firebrick or scrap metal under this end. You will find that welding uphill at a slight angle like this is much easier than welding on a flat surface. The molten metal will naturally build up at the rear of the puddle and you can get a weld of the proper height on the first pass.

Remelt the first tack weld and form a puddle. Then add metal to it from the welding rod. Whenever you add metal to the puddle keep the end of the rod in the puddle. Do not let it drip off. During welding, the blowpipe and the welding rod must be moved from side to side so that the flame can first heat one side of the

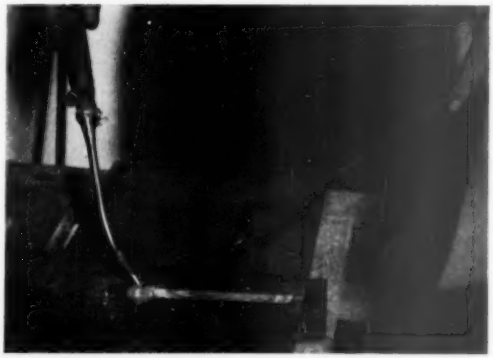


Fig. 4 Start the final weld at the end that has narrow spacing and weld from right to left. Keep the end of the rod in the puddle when you add metal

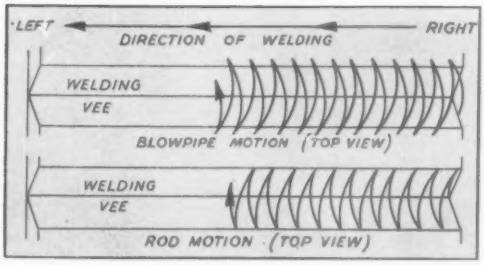


Fig. 5 Move the blowpipe and rod in semicircles but in opposite directions

vee and then the other. This prepares the plate edges for fusion with the molten puddle. Start to move the blowpipe and rod forward and the puddle will move too. Always be sure to melt the metal in the vee ahead of the puddle before you move the puddle forward. That is the most important thing to remember about steel welding. Add welding rod to the puddle until the weld is built up about $^1/_{16}$ in. higher than the surface of the steel plate. Be careful to get thorough penetration and complete fusion between the sides of the bevel and the molten puddle. If the puddle gets too hot or too large, draw back the flame or remove the welding rod for a few seconds.

Continue to add metal and move the blowpipe and rod forward until you are within $^1/_4$ or $^1/_8$ in. of the second tack weld. When you reach this point concentrate the flame on the face of the second tack weld near the bottom of the vee until you bring it to a melting condition. At the same time keep the welding rod in the edge of the flame so that it will be ready to add more weld metal as soon as you need it. When the face of the tack weld begins to melt, point the flame at the opening that is still left at the bottom of the vee. When this metal is melting add welding rod and form a puddle by filling in the opening. Then add welding rod and fill in the vee until the metal is as high as the rest of the weld. Gradually reduce the size of the puddle by drawing back the flame a little until the weld has been built up to the proper height. Then draw the flame away completely.

Weld as many pieces of plate as you need to get one piece 30 in. by 28 in. for the top. Join the table top to the side pieces by tack welds or a continuous weld all the way around the table. The rest of the table can be joined by either bronze welding or fusion welding.

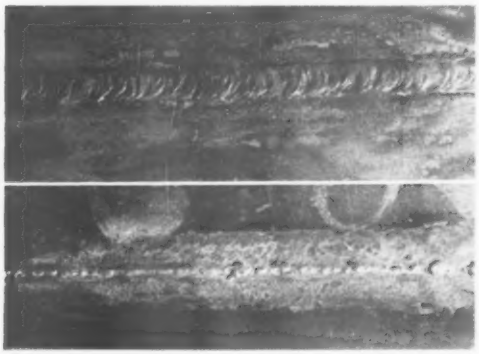


Fig. 6 (Top) In a good fusion weld the weld metal is higher than the plate and the ripples are even. (Bottom) Small beads should show through the bottom

HOW THE WELD SHOULD LOOK

When the weld has cooled, examine the underside. The weld should look like the one shown in Fig. 6. Small beads should show through the bottom of the vee to indicate thorough penetration. Figure 7 shows some common faults in steel welding. In *A* the weld was made with a slightly oxidized flame. The surface of the weld is pitted and the plate surface next to the weld shows heavy scaling. A weld that looks like this probably has very little strength. In *B* the weld was made with insufficient heat. There are also signs of "undercutting," that is, the weld metal in some places is lower than the surface of the plate. Either the base metal was not melted enough when the rod was added, the forward movement of rod and blowpipe was jerky or the blowpipe was held at too small an angle to the plate surface. Always be sure that the surfaces of the vee are actually melting as you add welding rod. Do not let the molten welding rod drip into the puddle but always place the rod in the puddle when you add metal. In *C* there was too much heat, and holes burned through the plate. If the base metal overheats, either the flame is too large, you keep it too long on one spot or the angle of the blowpipe is not right. Too steep an angle will often cause overheating.

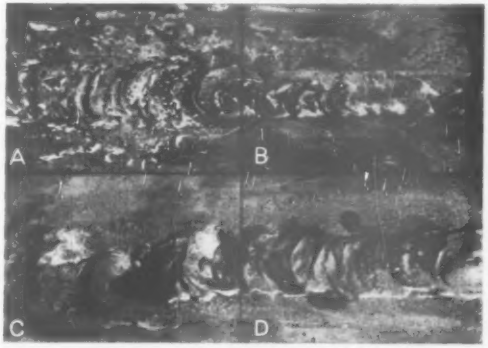


Fig. 7 (A) Made with an oxidising flame. (B) Not enough heat, poor fusion, and undercutting. (C) Too much heat, holes burned through. (D) Satisfactory weld

MAKING POSITION WELDS

Sometimes you will have to repair a piece of equipment in position. However, most position welding will be done on pipe. Here is how to make some of the more common types of position welds.

Vertical Position

When the part must be welded in the vertical position, as shown in Fig. 8, it is not always necessary to make tack welds. On this job tack welds were not used. Heat the parts with the blowpipe flame until the metal starts to melt. At the same time hold the rod at the edge of the flame. Add welding rod to the melting metal and form a puddle. Do not allow the puddle to become too large and keep it shallow by moving the welding rod. Build up a sort of ledge that will help support the rest of the weld. When this ledge has formed start to move the rod, blowpipe and puddle up the surface to be welded.

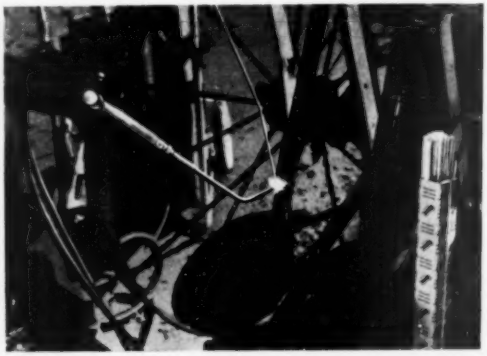


Fig. 8 When you make vertical welds, build up a ledge first. Do not let the puddle get too hot or it will run away

If the puddle seems to get too hot, draw back the flame slightly and it will cool. If the puddle gets too fluid it will get out of control and run down the face of the weld. This will not cause any particular harm on surfaces that have been welded but it will interrupt your welding and the final job may not look good. If metal runs over a spot that is not welded it should be melted before you add new metal. If you do not do this and add metal on top of the spilled material you will get what is called a "cold shut," and a weak weld.

Overhead Position

For a weld in the overhead position, point the welding flame almost directly into the vee, as shown in Fig. 9. The welding is done in almost the same way as for a flat position except that you will have to manipulate the flame and welding rod more often to move the puddle about and to keep it under control. To get proper penetration you must make sure that the sides of the bevel are at the proper welding temperature before you allow the molten puddle to flow on them.

Horizontal Position

To make a weld in the horizontal position, hold the

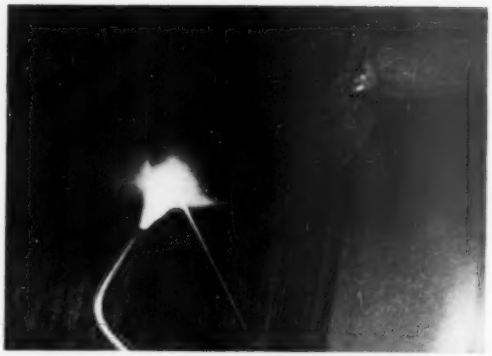


Fig. 9 You will find that most position welds will be made in pipe. For overhead welds point the flame almost directly into the vee

rod and blowpipe as shown in Fig. 10. Heat the metal to be welded and the welding rod the same as you did before. You will notice that the welding puddle has a slightly different shape than in the other welding positions.

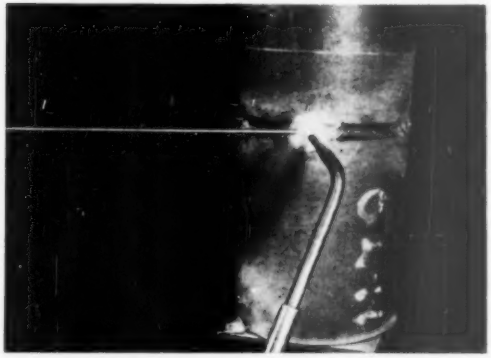


Fig. 10 For horizontal welds, hold the rod and blowpipe like this. The weld puddle will have a different shape than in other positions

You may have some trouble in keeping the puddle from running down to the lower edge of the weld. You will have to pay special attention to the direction of the welding flame. As you carry the weld puddle up the face of the weld to build up the upper edge, direct the flame against the upper edge only enough to melt the surface of the base metal and obtain proper fusion. This means that the flame should be moved about and not kept on one spot too long. Of course, it will probably take a little practice to learn just the right way to direct the flame on the welding rod to supply metal on the upper side of the weld and still not get the puddle so large and so fluid that it will run down out of control.

the AMERICAN WELDING SOCIETY

activities • related events

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A Subject and Authors Index for any or all of these years will be sent upon request.

Board of Directors Meeting

A Board of Directors meeting of the AMERICAN WELDING SOCIETY was held in the Hotel Statler, New York, N. Y., Parlor B, at 10:00 A.M. on Thursday, Sept. 22, 1949, with the following in attendance:

Board Members: C. A. Adams, G. E. Claussen, R. S. Donald, O. B. J. Fraser, H. O. Hill, J. H. Humberstone, T. M. Jackson, T. B. Jefferson, L. S. McPhee, H. W. Pierce, F. L. Plummer, G. N. Sieger and G. M. Trefts.

Staff: J. G. Magrath, *Secretary*, and F. J. Mooney, *Assistant Secretary*.

By invitation for limited periods: W. Spraragen, JOURNAL *Editor*, S. A. Greenberg, *Technical Secretary*, and J. Landau, A.W.S. *Auditor*.

Proposed Revised Rules to Govern Organization, Functions and Operations of Technical Committees of the AMERICAN WELDING SOCIETY

The Technical Activities Committee recommended to the Board of Directors that the Rules to Govern Organization, Functions and Operation of Technical Committees of the A.W.S. be approved as revised. The proposed revised rules were submitted to the Board of Directors and upon motion, duly seconded, were approved as submitted with exception of page 2, item 17, first sentence amended to read: "A technical committee shall circulate each proposed standard or proposed revision to an existing standard to a representative group of interested individuals in both consuming and producing section of industry for comment, and shall give proper consideration to such comments as are received prior to presentation of the standard for approval of the Technical Activities Committee."

Inclusion of Soft Soldering Within the Scope of the A.W.S. Technical Activities Committee

The Board unanimously approved that soft soldering should come within the scope of the A.W.S. technical committee activities.

R. D. Wasserman Offer to A.W.S. for Sponsoring of Three Prizes for Papers Covering "Improvements and Research in Torch and Furnace Nonfusion Metal Joining Processes"

The Board of Directors considered Mr. Wasserman's offer to A.W.S. for the sponsoring of three prizes for papers on the above subject and upon motion, duly seconded, agreed to permit Mr. Wassernan to sponsor prize papers under the conditions that (1) the prize be called the "R. D. Wasserman Prize" and (2) that the prize not be misused by its utilization in any fashion, as a vehicle for advertising or publicity of a proprietary nature, other than such publicity as released through the AMERICAN WELDING SOCIETY. The Board referred the entire matter to the Committee on Awards for necessary action thereon.

Annual Reports

The annual reports of the various Committees of the SOCIETY were accepted as submitted. (Copies to members are available on request.)

Acceptance of Minutes of Finance Committee Meeting

R. S. Donald, A.W.S. Treasurer, reviewed the minutes of the Finance Committee Meeting held on Sept. 15, 1949. He pointed out the SOCIETY suffered a net loss of $22,347.67 for an 11-month period ended Aug. 31, 1949. Reasons advanced for the loss were (1) JOURNAL advertising revenue fell off considerably, (2) the additional expense of the employment of an advertising agency and (3) the anticipated receipts from the membership campaign did not measure up to expectation. After careful review of the minutes, the Board accepted the Minutes of the meeting as circulated.

Acceptance of Statement of Income and Expense for Eleven-Month Period Ended Aug. 31, 1949

J. Landau, A.W.S. Auditor, reported that the total income for the fiscal year aggregated $207,900, an increase of $22,800 over the preceding year. This increase was caused for the most part by an increase in the rates of membership dues. JOURNAL advertising revenue for the 11-month fiscal year amounted to $53.000

The total expenses for the year amounted to $230,000 as against $205,500 for the previous period. Most of the increase was caused by increased JOURNAL costs and the costs of the membership drive.

Cash in banks and on hand as of Aug. 31, 1949, was $71,778.78. Of this amount, $28,329.81 represents dues collected for the new membership year, $6208.94 held in reserve for sponsoring awards and $22,459.39 in the *Welding Handbook* reserve account.

The operations for the 11-month period ended Aug. 31, 1949, resulted in an excess of expense over income of $22,347.67.

After review of the financial statement, the Board accepted the Auditor's report, as submitted.

Acceptance of Proposed Budget of Income and Expense for the Fiscal Year Commencing Sept. 1, 1949

R. S. Donald stated that as Chairman of the Finance Committee and Treasurer he had requested the Secretary and Auditors to present a balanced budget to his Committee. He stated that the Finance Committee at its meeting on Sept. 15, 1949, approved of a balanced budget for the fiscal year commencing Sept. 1, 1949. He commented that the balanced budget involved the following major changes:

1. Consideration of adjustment in A.W.S. advertising arrangements.
2. Reduction in expense of the third edition of the *Welding Handbook*.
3. Nonpublication of a Membership Directory during the 1949–50 fiscal year.
4. Nonpublication of general informational bulletin on SOCIETY but rather to utilize any available supply of the SOCIETY's brochure.
5. Elimination of $100 honorarium to the 1949 Educational Series Lecturer.
6. Reduction in personnel.

J. G. Magrath, A.W.S. Secretary, proposed that the financial records of the SOCIETY be examined after a three-month period for further adjustments, that is, upward if providential improving conditions allowed; downward if conditions indicated such advisable. The Board approved of this action.

Elimination of $100 Honorarium to the 1949 Educational Series Lecturer

Due to the financial condition of the SOCIETY, the Board moved to dispense with grant of $100 to the 1949 Educational Series Lecturer.

1950 Adams Lecturer

After due consideration of the 1950 Adams Lecturer candidates, proposed by the Awards Committee, thirteen ballots were cast which resulted in the selection of C. H. Jennings as Lecturer.

30% Discount to "CARE"

The Board approved of special allowance of a 30% discount on the purchase of A.W.S. books, specifications and other published literature to the nonprofit corporation "Cooperative for American Remittances to Europe, Inc." provided this discount rate will not cost A.W.S. money.

Definition of Term "Welding Engineer"

The Educational Committee of the A.W.S. submitted definition of the term "Welding Engineer" to the Board for approval and recommended that copies of this definition be circulated to a selected list of individuals with a specific request for constructive criticism, and that it be published as a definition in THE WELDING JOURNAL with request for comments. Herewith follows definition of term "Welding Engineer" as submitted by the Educational Committee and upon motion, duly seconded, approved by the Board of Directors:

"A Welding Engineer is one who, by reason of his special knowledge of the mathematical and physical sciences and the principles and methods of engineering analysis, acquired by professional education and/or practical experience, is qualified to practice welding engineering as defined in the following paragraph."

"The Practice of Welding Engineering involves a knowledge of three basic areas in engineering: (1) the design of machines, structures and equipment as well as the design of suitable connections; (2) the materials of engineering with particular reference to metals, gases and refractories; and (3) the processes, procedures and equipment of the welding industry. The practice of welding engineering includes such professional services as consultation, investigation, evaluation, planning, design or responsible supervision of construction or manufacturing when such professional service requires the application of engineering principles and data."

Appointment to A.W.S. Committee on I.I.W.

The Board of Directors approved the request of the A.W.S. Committee on International Institute of Welding that Howard Biers be appointed as Member-at-Large to their Committee and to serve for a three-year term.

Technical Activities Committee Recommendations

Results of favorable letter ballot sent to the Directors under date of July 19, 1949, concerning recommendations of the Technical Activities Committee were as follows:

1. Appointment of A.W.S. Representatives on Inter-Society Committee on Corrosion.

2. Appointment of A.W.S. Representative on A.S.M.E. Committee on Penstocks.

3. Annual Reports of Technical Committees and A.W.S. Representatives on Technical Committees of other organizations.

4. Approval of Proposed Revision to A.W.S.-A.W.W.A. Tentative Specifications for Field Welding of Steel Pipe Joints.

5. Approval of Proposed Revised Recommended Practices for Resistance Welding.

Renewal of A.W.S. Bond

Renewal of $12,500 blanket position bond for A.W.S. staff, premium of $375 for three-year period, was submitted to the Board of Directors as a matter of information only.

Change in Requirements of an Active Section and the Establishment of a Semiactive Section

J. G. Magrath, Secretary, tendered the opinion that no longer is a section supportable on the basis of twenty-five members as required by the National By-Laws (Article V, Section 2) and consequently suggested that the following order be established:

(*a*) An *Active Section* may not have fewer than fifty members. Any section having less than fifty members would lose identity of an *Active Section*.

(*b*) That there be established the classification of a *Semiactive Section* in which there are less than fifty members but more than twenty-five. A *Semiactive Section* would not receive the $100 anniversary check but instead would receive a prorated anniversary payment for the order of twenty-five to fifty members, i.e.—for 45 members, receive $90; for 37 members, $74; for 26 members, $52; for 24 members, $0.00. Any Section having less than twenty-five (25) members would lose its identity as a Semiactive Section. It would become an *Inactive Section*.

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The Board of Directors, upon motion, duly seconded, approved of this change in requirements for an Active Section and the establishment of a Semiactive Section and directed that these changes be reported to the Constitution and By-Laws Committee for necessary adjustment in the National By-Laws. It was recommended that the classifications "Active" and "Semiactive" Sections might well be named "Class I" and "Class II" Sections.

Invitation Extended to A.W.S. to Cooperate with the A.I.E.E. Conference on Electric Welding in Conducting a Special Technical Conference on Electric Welding in Detroit, April 5–7, 1950

The Board of Directors accepted invitation to cooperate with the A.I.E.E. Conference on Electric Welding in conducting a special technical conference on electric welding in Detroit, April 5–7, 1950. The Board approved the appointment of J. G. Magrath to serve on this committee and for the name, AMERICAN WELDING SOCIETY, as a cooperating Society, to be placed on their letterhead in advertising and any announcements concerning meeting.

Alexis Caswell Memorial Resolution

Appointment by Acting President Fraser of Special Committee, consisting of T. P. Hughes and E. Hixson, for purpose of drawing up suitable memorial resolutions for Alexis Caswell, deceased, was confirmed and by vote of the Board the resolution prepared by this Special Committee was adopted for the records and transmittal to the family of Mr. Caswell.

A.S.A. Special Meeting of Finance Committee

T. D. Jolly, President, American Standards Association, sent an invitation to G. N. Sieger, President, A.W.S., to attend a special meeting of their Finance Committee to be held on Sept. 30, 1949, at 10:00 A.M.

In that Mr. Sieger could not attend, he appointed O. B. J. Fraser and J. G. Magrath to represent him at this meeting.

Certificate for M. M. Kelly, Secretary Emeritus

Dr. C. A. Adams prepared a certificate to be presented to M. M. Kelly at a special luncheon which was held on Wednesday, Oct. 19, 1949, during th week of the Annual Meeting. The Board unanimously approved this certificate and voted that subject certificate be suitably illuminated and framed for presentation to M. M. Kelly at the 1949 Annual Meeting of the SOCIETY.

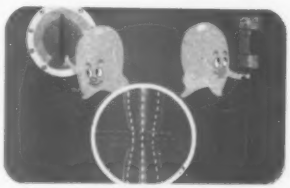
Resolution of Appreciation to President G. N. Sieger

T. B. Jefferson proposed a resolution of appreciation to President G. N. Sieger in the order following:

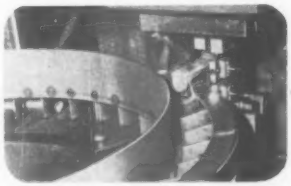
"Whereas Mr. George N. Sieger has during the past year served the AMERICAN WELDING SOCIETY meritoriously as its President, presiding at the greater number at its Board of Directors and other important committee meetings, visiting certain of its sections for the purpose of strengthening and promoting the SOCIETY'S wel-

Can Resistance Welding Cut YOUR ASSEMBLY COSTS?

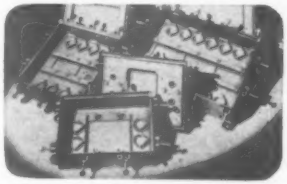
See this film and find out!



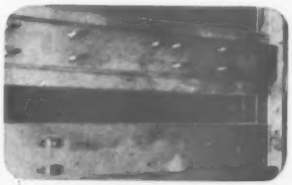
1. "THIS IS RESISTANCE WELDING", a full-color sound motion picture prepared by General Electric, will appeal to management, engineers, and shop men. Filmed with the layman in mind, this picture makes liberal use of cartoons (above) to simplify . . .



2 . . . the more technical aspects of resistance welding. Principal objective of the film, though, is to explain how resistance welding cuts fabricating and assembly costs. One application shown is the assembly of a blower rotor (above) where clearances . . .



3 . . . had always been a problem. Resistance welding cut manufacturing time by 75%! Another big saving dramatized in the film is the case of the switch boxes (above). These were formerly sand cast with holes individually located, drilled and tapped.



4. These are now completely welded on a continuous basis and production is up from a few hundred to 1000 units a day! The audience is also shown how another manufacturer welded studs on a steel cubicle framework (above) in one operation . . .

5 . . . instead of the seven formerly required! And for the cost-conscious executive, there's the story about the railroad that used resistance welding to save expensive seamless tubing (above). To give you a "preview" of this worthwhile film let us send you this . . .

6. RESISTANCE WELDING MANUAL . . . FREE! It's jam-packed with the kind of information on resistance welding you want. [Complete program consists of full-color 16mm film, manual, "highlights" booklets.] MAIL THE COUPON TODAY!

FREE *to business management!*

General Electric Co., Section E684-14
Schenectady 5, N. Y.

Attach to your business letterhead

☐ Please send me a complimentary copy of the G-E Resistance Welding Manual (GES-3393). (Extra copies at regular manual price—$1.00.)

☐ I'd like to borrow a 16mm print of the film from your nearest film library.

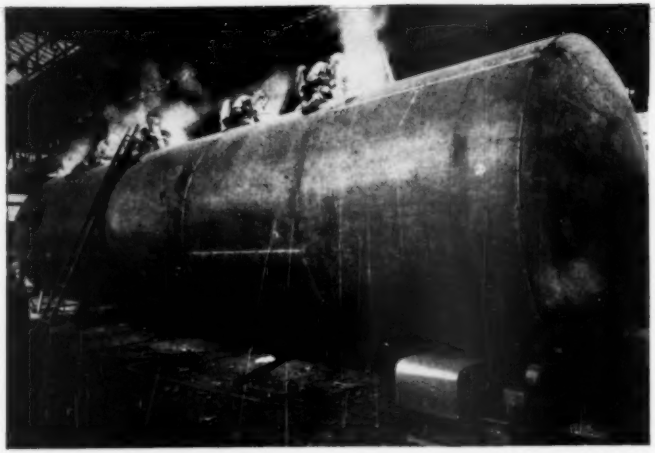
Name _____ Title _____

Company _____

Street _____

City _____ State _____

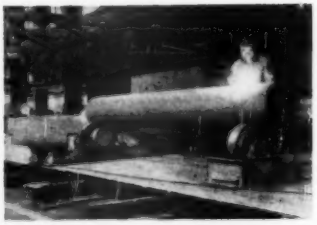
GENERAL ELECTRIC



Less Handling—More Welding

It's handling that costs most in welding . . . the crane work or manual labor in positioning the pieces—plus the welder's *waiting* time.

Get more arc-time from every hour by using Worthington-Ransome Turning Rolls to handle tanks, drums or any type of cylindrical vessel regardless of size. They continually bring the work into position for efficient, economical *downhand* welding (manual or automatic) with heavier electrodes which means fewer passes and better welds.



50% greater production on both repetitive and job work has been reported by users.

Capacities from 3 to 75 tons, up to 14 ft. diam., stationary or self-propelled. (Rolls for heavier or larger work also available.)

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WORTHINGTON PUMP AND MACHINERY CORPORATION

Welding and Assembly Positioning Equipment Division

DUNELLEN, NEW JERSEY

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Worthington Pump and Machinery Corp.
Dunellen, N. J.

Please send Bulletin 228 on Worthington-Ransome Turning Rolls.

NAME.....

COMPANY.....

ADDRESS.....

50% PRODUCTION UP

Turning Rolls
Welding Positioners

LABOR COSTS DOWN

fare, providing his guidance throughout the year, injecting his zeal into all the SOCIETY's activities, all despite a prolonged period of illness and convalescence—

Therefore, the Society as represented by its Board of Directors, commends Mr. G. N. Sieger for his fortitudinous resistance to the illness which attacked him, for his surmounting the physical handicaps which temporarily beset him and extends its sincerest appreciation for his guidance, activity, service and very productive efforts during his term as President."

O. B. J. Fraser, First Vice-President, momentarily assumed the Chair, relinquished by President Sieger. Mr. Jefferson's motion was duly seconded and approved by the Board of Directors.

Seventh Congress of Pan American Architects Extends Invitation

O. B. J. Fraser, First Vice-President, submitted an invitation extended to the SOCIETY's Members by the Seventh Congress of Pan American Architects to assist and participate in their activity at the National College of Architects of Cuba in Havana on Dec. 8-14, 1949. It was moved, seconded and approved that the Secretary should relay the invitation to all A.W.S. National Officers and to all A.W.S. Section Secretaries for announcement at their next Section Meeting. Also, for the Secretary to inform A.W.S. members residing in Cuba of this affair.

Date, Time and Place of Next Meeting

The next meeting of the Board of Directors will be held in Cleveland, Ohio, on Oct. 19, 1949 at 3:00 P.M.

Standing Committees of the American Welding Society 1949-50

Approved by Board of Directors October 19th

Executive Committee: O. B. J. Fraser, *Chairman*, H. W. Pierce, C. H. Jennings, R. S. Donald, T. B. Jefferson, D. Arnott and H. O. Hill.

Finance Committee: R. S. Donald, *Chairman*, D. Arnott, J. H. Humberstone, H. W Pierce, T. M. Jackson, C. I. MacGuffie and F. J. Mooney, *ex-officio*.

Welding Journal Committee: A. G. Oehler, *Chairman*, W. Spraragen, *Secretary*, F. H. Frankland, C. P. Croco, T. C. Fetherston, J. Haydock, E. I. Larsen, C. I. MacGuffie, L. C. Bibber, P. W. Swain, G. Van Alstyne and J. G. Magrath, *ex-officio*.

Committee on Admissions: G. Schneider, *Chairman*, W. B. Bunn, Jr., P. M. Mattern, R. H. Taylor and W. A. Howard.

Membership Committee: H. C. Neitzel, *Chairman*, E. Krisman, *Secretary*, H. S. Swan, G. E. Claussen, L. C. Stiles, F. L. Plummer, J. Grodrian, R. L. Townsend, W. F. Boyle, T. B. Jefferson and I. Morrison.

Section Advisory Committee: R. L. Townsend, *Chairman*, J. G. Magrath, *Secretary*, H. W. Swan, G. E. Claussen, L. C. Stiles, F. L. Plummer, J. Grodrian and W. F. Boyle.

Convention Committee: Homer R. Morrison, *Chairman;* Selectee, *Vice-Chairman,* Chicago Section; J. G. Magrath, *Secretary;* F. J. Mooney, *Assistant Secretary;* R. S. Donald, *Treasurer;* G. O. Hoglund, *Chairman of Program Committee;* W. Spraragen, *Secretary of Program Committee;* G. Van Alstyne, *Chairman of Publicity Committee;* C. L. Combes, *Secretary of Publicity Committee;* C. I. MacGuffie, *Chairman of Manufacturers Committee;* R. A. Wyant, *Chairman of Educational Committee* and L. C. Monroe, *Secretary of Chicago Section.*

Program Committee: G. O. Hoglund, *Chairman,* W. Spraragen, *Secretary,* A. F. Chouinard, E. V. David, H. R. Morrison, La Motte Grover, A. A. Holzbaur, T. E. Jones, R. E. Powell, J. W. Sheffer, R. D. Thomas, Jr., E. Vom Steeg, Jr., J. L. Wilson, B. L. Wise, R. A. Wyant and Ross J. Yarrow.

Manufacturers Committee: C. I. MacGuffie, *Chairman,* J. L. Adank, W. H. Bleecker, R. W. Boggs, M. S. Clark, A F. Davis, J. D. Gordon, J. R. Hunter, R. J. Keller, T. S. Long, N. C. Miller, W. A. Mudge, W. W. Reddie, A. C. Runnette, Earle C. Smith, R. D. Thomas, J. B. Tinnon and G. Van Alstyne.

Publicity Committee: G. Van Alstyne, *Chairman,* C. L. Combes, *Secretary,* H. S. Card, A. F. Davis, L. C. Monroe, M. L. Smith, W. Spraragen, T. C. Fetherston J. F. Wagner and J. D. Gordon.

Public Relations Committee: H. F. Reinhard, *Chairman,* D. H. Corey, A. F. Davis, C. I. MacGuffie, R. E. McFarland, R. P. McMillan, A. M. Meyers, Earle C. Smith and Edwin O. Williams.

Constitution and By-Laws Committee: F. W. Davis, *Chairman,* H. O. Hill and A. J. Raymo.

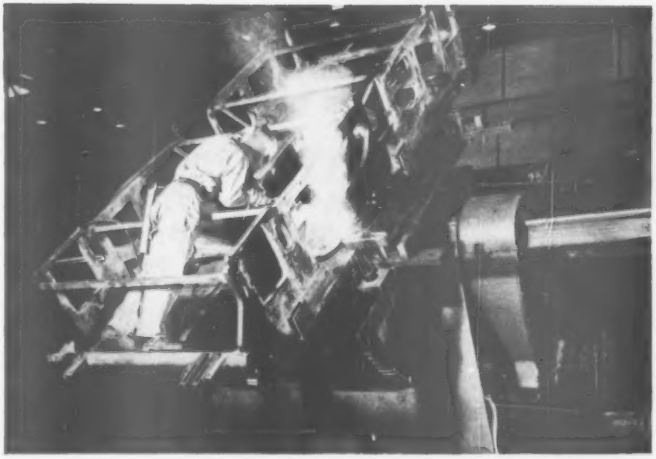
Educational Committee: R. A. Wyant, *Chairman,* F. J. Mooney, *Secretary,* M. L. Begeman, H. C. Boardman, W. J. Brooking, G. E. Doan, R. D. Stout (alternate for G. E. Doan), A. C. Good, R. S. Green, R. J. Krieger (alternate for R. S. Green), J. Heuschkel, F. Jonassen, P. E. Kyle, C. A. Peterson, G. N. Sieger, H. M. Priest, H. E. Rockefeller, F. W. Scott, J. R. Stitt, L. E. Wagner and Furman F. Williams.

Committee on Awards: R. H. Aborn, *Chairman* (retires 1950), C. E. Jackson (retires 1951), S. L. Hoyt (retires 1952), E. R. Seabloom (retires 1953) and H. M. Priest (retires 1954).

R. W. M. A. Jury of Award: W. E. Crawford, *Chairman* (retires 1950), R. M. Wilson (retires 1951), R. A. Wyant (retires 1952), W. E. Smith (retires 1953) and B. L. Wise (retires 1954).

Committee on Reserve Funds: J. B. Tinnon, *Chairman* (retires 1951), A. C. Weigel (retires 1950), O. B. J. Fraser (retires 1952), J. L. Wilson (retires 1953), J. J. Crowe (retires 1954) and R. S. Donald, *ex-officio.*

Technical Activities Committee—appointed by Technical Activities Committee: C. H. Jennings, *Chairman,* C. D. Evans, *Vice-Chairman,* S. A. Greenberg, *Secretary,* H. M. Priest, O. R. Carpenter, J. L. Christie, R. W. Clark, J. H. Deppeler, R. W. Emerson, L. E. Grant, T. R. Higgins, H. O. Hill, W. W. Hurlbut, T. W.



More Arc-Time Per Hour

You pay your welders for welding . . . so the time it takes them to *position* the work—or themselves—is *lost* welding time.

But a Worthington-Ransome Positioner quickly tilts and rotates the work for practically *continuous* welding—always in the efficient *downhand* position that permits using heavier electrodes for *quicker, neater, better* welds.

Mass production or job welding . . . small pieces or "crane" work . . . automatic or manual welding—Worthington-Ransome Positioners quickly *pay* for themselves with increased production, lowered labor costs—up to 50%.

Capacities from 100 lb. to 20 tons.

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WORTHINGTON PUMP AND MACHINERY CORPORATION

Welding and Assembly Positioning Equipment Division

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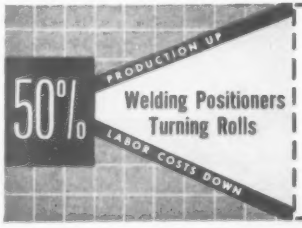

Worthington Pump and Machinery Corp.
Dunellen, N. J.

Please send Bulletin 210C on Worthington-Ransome Welding Positioners.

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Q. CAN YOU HEAT A HIGH PRESSURE, WELDED PIPE JOINT TO 1700° F, 30 FEET UP IN THE AIR?

A. The Smith Dolan System can EASILY handle this problem of Preheating Stress Relieving and Normalizing to 1700° F on Carbon and Stainless Steels!

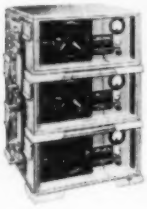
Boiler down-comer partially wrapped for stress relieving.

1. SAFE TO USE EASILY APPLIED ASSURED RESULTS — Smith Dolan Heating Apparatus is so simple to handle that it can be operated by job personnel. Because it delivers consistently perfect results under safe conditions, it assures you of minimum job cost.

2. THOROUGH PENETRATION — It is no problem to achieve thorough heating of heavy sections with precise control in minimum time.

3. MEETS METALLURGICAL & CODE REQUIREMENTS — Proper heating is delivered according to set specifications and requirements of Boiler and Piping codes.

4. LABORATORY CONTROL UNDER FIELD CONDITIONS — Smith Dolan Induction Heating Apparatus is designed and engineered with automatic or semi-automatic controls. Therefore, you obtain accurate, consistent results under field conditions, with a permanent record of each job always available.



NEW MODEL U-P — *Patented Smith-Dolan System, portable, low frequency induction heater, three-high stack (shown) 30 kva—10 kva per unit. Buy one or stack 2 or 3 for increased capacity. Buy what you need —build as you go.*

INDUCTION CONTROL CABINET *used with Model U-P units (shown) and Model GC Duplex 120 or 150 kva induction heaters (shown in catalog).*

ELECTRIC ARC can supply equipment for ANY TYPE OF JOB—equipment that can be *purchased outright or rented*. From what other source could you possibly obtain such wide latitude in planning for every job in preheating and stress relieving before welding and normalizing? Today, more than ever, Electric Arc equipment is specified where other methods are too costly or impractical. Write for informative catalog.

ELECTRIC-ARC

ELECTRIC-ARC, INC.
161 JELLIFF AVE., NEWARK 8, N. J.
Welding Equipment, Electrodes & Supplies

Morgan, F. J. Pitcher, H. F. Reinhard, M. F. Sayre, Wilson Scott, J. L. Wilson and A. B. Wrigley.

Those appointed by the Board of Directors are: C. H. Jennings, Gilbert S. Schaller and A. N. Kugler.

Code of Principles of Conduct Committee: D. Arnott, *Chairman* (retires 1950), A. C. Weigel (retires 1951), W. F. Hess, (retires 1952), L. W. Delhi (retires 1953) and H. O. Hill (retires 1954).

Honorary Membership and Honorary Directorship Committee: O. B. J. Fraser, *Chairman*, H. W. Pierce, C. H. Jennings, H. O. Hill and G. N. Sieger.

Special Committee on Handling Requests for Foreign Libraries: A. C. Weigel, *Chairman*, D. Arnott and W. Spraragen.

CASWELL MEMORIAL RESOLUTION

Adopted by Board of Directors

WHEREAS, the death of Alexis Caswell was a great loss as an active and respected member of the SOCIETY.

WHEREAS, he was closely associated with the Northwest Section of the AMERICAN WELDING SOCIETY having served as secretary-treasurer from the time of its organization in 1937 until 1947.

WHEREAS, his faithful and continuous service and sound guidance contributed substantially to the success and growth of the Northwest Section and thus growth in the SOCIETY.

WHEREAS, his creative ability, his strong character, his friendliness acquired him great personal respect and affection from those who worked with him and knew him, now therefore, be it

Resolved that through the Board of Directors and its officers, the AMERICAN WELDING SOCIETY hereby expresses sincere appreciation for Alexis Caswell's services to the SOCIETY; and be it further

Resolved that this Resolution be spread upon the records of the SOCIETY, with deep sympathy and regret, and a copy of the Resolution transmitted to Mrs. Alexis Caswell and his family.

TORCH WELD ALUMINUM ?

Here's a kettle full of proof

Right here in Alcoa's job shop we've welded upwards of 40,000 kettles. Good, tight seams, too. Have to be, to take the beating a steam kettle gets.

Why I've been welding aluminum over twenty years. Some of it up to one inch thick. No trick to it, just follow the simple procedures.

I tell you, manufacturers who don't investigate welding as an economical way to join aluminum assemblies are missing a bet. Especially when most of the information you need is in the free book, "Welding Alcoa Aluminum". Ask your nearby Alcoa Sales Office for a copy, or write ALUMINUM COMPANY OF AMERICA, 1933M Gulf Building, Pittsburgh 19, Pennsylvania.

ALCOA FIRST IN ALUMINUM

ALCOA ALUMINUM

INGOT • SHEET & PLATE • SHAPES, ROLLED & EXTRUDED • WIRE • ROD • BAR • TUBING • PIPE • SAND, DIE & PERMANENT MOLD CASTINGS • FORGINGS • IMPACT EXTRUSIONS
ELECTRICAL CONDUCTORS • SCREW MACHINE PRODUCTS • FABRICATED PRODUCTS • FASTENERS • FOIL • ALUMINUM PIGMENTS • MAGNESIUM PRODUCTS

NEWS OF THE INDUSTRY

Weltronic Stays on the Job

Weltronic Co., 19500 W. 8 Mile Road, Detroit, announces its return to full production after the disastrous fire which occurred Aug. 17, 1949, and destroyed its building and stock.

After only a brief interruption, the company is able to fill orders immediately from built-up stocks of all standard controls and combinations.

Amsco Products

American Manganese Steel Division of American Brake Shoe Co., announces the appointment of the Whitehead Metal Products Co., Inc., as distributors of its complete line of Amsco welding products. This line consists of various types of rods and electrodes for hard facing and repair work, including the newly developed tungsten carbide rods.

The Whitehead Co. operates warehouses in major cities in five Eastern states including New York, New Jersey, Pennsylvania, Massachusetts and Maryland.

New York City Meeting Attracts 63 Delegates

A Meeting of Distributors and Manufacturers in the Eastern Zone at the Hotel New Yorker in New York City on Thursday, September 29th, was attended by 63 delegates who were unanimous in their feeling that the Meeting was extremely constructive. Bob McCracken, R. S. McCracken & Sons, Inc., Philadelphia, did an outstanding job as the presiding officer and from comments heard following adjournment, it was evident that everyone benefited from the constructive discussions and exchange of ideas that took place.

Victor Purchases Mills Alloys

Victor Equipment Co. announces the purchase of the business and assets of the Los Angeles manufacturing firm of Mills Alloys, Inc., 11320 S. Alameda St., Los Angeles, Calif. The purchase includes the purchase of the physical assets of Mills Alloys such as inventory, machines and equipment, the company's trade name, all patents, trademarks and formulas. The manufacturing facilities purchased by Victor will continue to be located at the leased site now occupied by Mills Alloys, and will be designated as the Alloy Rod and Metal Division of Victor Equipment Co.

Mills Alloys has been in business for more than 25 years and is a well-known manufacturer of all types of blasting nozzles and all types of tungsten carbide hard-surfacing rod. Tungsten carbide rod is the hardest metal known, ranking next to commercial diamonds, and is used for depositing cutting surfaces on all drilling tools, scraping blades, and digging equipment. These products of Mills, which in the future will be manufactured by Victor, will complement the present Victor manufactured line of gas welding and cutting equipment and allied equipment.

Devaluation Causes Philips to Transfer Manufacturing Plant

The long arm of devaluation, which reduced the value of foreign currency, has affected the products of an American firm whose manufacturing activities will be partly replaced by import. It has necessitated that the North American Philips Co., Inc., concentrate its manufacturing activities in fewer plants.

Mr. van den Berg, their President, mentioned that the devaluation was making it possible to offer several other imported products at considerably reduced prices.

Similarly, a new type of contact welding electrodes, offering improved weld quality and lower welding costs, can now be bought by industrial users at savings as high as 50% over original prices on certain items.

Welded Steel Pipe Mill

Houston, Tex., has been chosen as the site for a new electric welded steel pipe mill to be built by the Consolidated Western Steel Corp., it was announced by Alden G. Roach, President of this United States Steel subsidiary.

Preliminary construction work has begun on property owned by Consolidated Western near the Houston Ship Channel. It is expected that the new plant will be in operation in the Spring of 1950.

The new facilities will provide an annual capacity of 100,000 net tons of 24-in., and larger, diameter electric welded and expanded steel pipe, and will enable Consolidated Western Steel Corp. to compete in the Texas area, and particularly in the market for large diameter pipe required for long distance oil and gas-pipe lines. The new plant's capacity will be approximately 50 miles of large diameter pipe a month.

At present United States Steel has no facilities for the production of this type of pipe east of the Rocky Mountains or south of the Pittsburgh, Pa., area.

"In the selection of Houston as the location for its new mill, Consolidated Western Steel Corporation is carrying out a plan to provide Texas fabricated pipe to the growing network of oil and gas transmission lines originating in the Lone Star State," Mr. Roach said.

"Consolidated Steel has played a part in the industrial development of Texas for many years, particularly at Orange. I am happy and proud to announce that our new plant at Houston and our modernized facilities at Orange will enable us to contribute further to the growing productive strength of this great State."

Coast Guards List Type R Electrode for Merchant Ships

Shipbuilders, welders, designers and purchasing executives have just been advised by Metal & Thermit Corp. that they may now specify Type R arc-welding electrodes for Coast Guard-inspected work. The Merchant Marine Technical Division, U.S.C.G., this month accepted M & T Type R electrodes (A.W.S. classification No. E6010, D.-C. reverse polarity) for listing in the equipment Lists (CG 190) for Merchant Vessels and the Proceedings of the Merchant Marine Council. Tested in the presence of a Surveyor of the American Bureau of Shipping the electrode was found to meet the requirements of A.S.T.M. Designation A233–48T.

Metal & Thermit Corp. produces the Type R electrode in seven sizes—$^{3}/_{32}$ x 14 in.; $^{1}/_{8}$ x 14 in.; $^{5}/_{32}$ x 14 in.; $^{3}/_{16}$ x 14 in.; $^{7}/_{32}$ x 18 in.; $^{1}/_{4}$ x 18 in. and $^{5}/_{16}$ x 18 in. The listing shows approvals for the $^{3}/_{32}$-, $^{1}/_{8}$-, $^{5}/_{32}$- and $^{3}/_{16}$-in. sizes in all welding positions; the $^{7}/_{32}$- and $^{1}/_{4}$-in. sizes in horizontal, fillet and flat positions; and the $^{5}/_{16}$-in. size in flat positions only.

Physical properties of welds made with the electrode are as follows: tensile strength—63,000 to 75,000 psi.; yield point—54,000 to 61,000 psi.; elongation in 2 in.—22 to 31%. The electrode is characterized by excellent arc stability, minimum spatter and a slag easy to remove.

Air Reduction Management Changes

In an announcement made public recently, J. A. Hill, president of Air Reduction Co., Inc., announced the appointment of H. R. Salisbury as president of Air Reduction Sales Co. Mr. Salisbury has been with the organization over twenty-three years in various executive capacities. Appointed Vice-Presidents were H. F. Henriques (General Sales), J. J. Lincoln, Jr. (Railroad Sales and Sales Services), S. B. Stouffer (Distribution), N. L. Wisser (Field Office Management). Other officers of Air Reduction Sales Co. are: C. G. Andrew, Vice-President, Operating; J. D. Gunther, Secretary; W. Winters, Treasurer and J. E. Slater, Controller.

ARCOS
LOW HYDROGEN
ELECTRODES

FOR WELDING HIGH STRENGTH LOW ALLOY STEELS

ARCOS pioneered the low hydrogen type of electrodes during the war years to produce sound welds when welding low alloy steels such as chrome-molybdenum, vanadium and nickel alloy steels.

ARCOS *quality-controlled* low hydrogen electrodes

- ★ Require no preheat on many jobs.
- ★ Have high impact values.
- ★ Give a complete range of tensile properties with high ductility.

	Yield Strength, psi	Tensile Strength, psi	Elongation in 2"	Reduction in Area
Manganend 1M	70- 85,000	90-100,000	20-30%	40-70%
Manganend 2M	85-105,000	100-125,000	10-20	15-20
Nickend 1	62- 69,000	70- 80,000	25-30	50-60
Nickend 2	65- 75,000	80- 90,000	20-30	45-60

ARCOS Low Hydrogen Electrodes are recommended for welding:

- ★ Low alloy cast steels.
- ★ Low alloy high tensile strength rolled steels.
- ★ High carbon steels.
- ★ High carbon to mild steels.
- ★ Free machining steels.

Send for ARCOS Bulletin 1249 containing more specific information on the use of ARCOS LOW HYDROGEN ELECTRODES.

ELECTRODES • COILED WIRE • BARE ROD

New "Welded Bridges of the Future" Program for 1950

The taxpayers of the United States have an estimated $10,000,000,000 invested in bridges and spend an estimated $100,000,000 every year to maintain them. To promote the building of better bridges for less money The James F. Lincoln Arc Welding Foundation is sponsoring the second "Welded Bridges of the Future" program.

A first award of $5000 will be made for the best design submitted in the 1950 program of a welded 250-ft. highway bridge. The second award will be $2500, the third, $1250. Ten honorable mention awards of $200 each will also be given, making a total of $10,750 in awards to designers and engineers. Any designer or engineer who considers himself qualified to enter the program is eligible for participation. The competition opens Nov. 1, 1949 and closes June 30, 1950.

The all-welded bridge to be designed is a two-lane through highway bridge with a span of 250 ft. The type of steel and the loading conditions for the bridge are specified, but these are the only limitations by the program on designers' ingenuity and originality. Designers are encouraged to develop new design concepts, new steel shapes, new fabricating and erecting methods and evolve changes in existing specifications providing such new ideas are consistent with good engineering practice and are practical.

The Foundation believes, according to Dr. E. E. Dreese, Chairman of the Board of Trustees, that bridge design has been limited and restricted by existing steel shapes and methods which were developed before the possibilities of welding were known. It is felt that considerable progress in the evolution of bridge design will result if designers are given the opprotunity and incentive to design a bridge expecially for welded fabrication, limited only by restrictions of practicality and safety.

The Rules and Conditions for the program have been prepared with the advice and help of a Rules Committee consisting of prominent bridge engineers and designers in leading universities, consulting firms and fabricating companies. The Honorary Chairman of the Rules Committee is Wilbur M. Wilson, Emeritus Research Professor of Structural Engineering, University of Illinois. The Jury of Award for selecting the best designs will consist of members of the Rules Committee.

The Rules and Conditions brochure may be obtained by writing to The James F. Lincoln Arc Welding Foundation, Cleveland 1, Ohio.

B. A. Bakhmeteff to Head Engineering Foundation

The Engineering Foundation elected Dr. Boris A. Bakhmeteff, Consulting Engineer and Professor of Civil Engineering, Columbia University, its Chairman at the annual meeting of its Board in the Engineering Societies Bldg., 29 W. 39th St., New York City, it was announced recently by John H. R. Arms, Secretary. Dr. C. G. Suits of the General Electric Co. was chosen Vice-Chairman. Re-elected officers included Frank T. Sisco as Technical Director, and John H. R. Arms as Secretary.

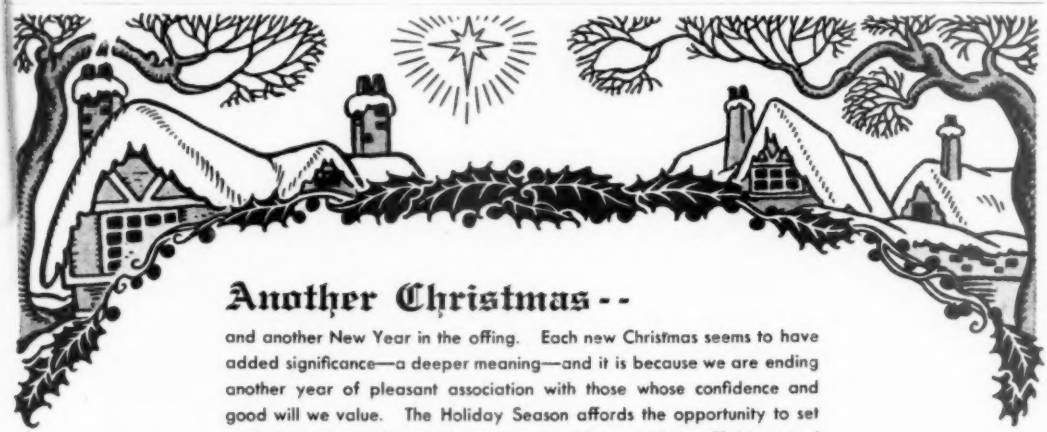
Dr. Bakhmeteff was also appointed Chairman of the Executive Committee. Other members of the Executive Committee are: Mr. Arms as Secretary; Dr. Suits; Dr. A. B. Kinzel, Vice-President of the Union Carbide and Carbon Research Laboratories, Inc.; Herman Weisberg (A.S.M.E.), Mechanical Engineer in the Electrical Engineering Department of the Public Service Company of New Jersey; and D. A. Quarles, Vice-President of the Bell Telephone Laboratories, Inc.

The Research Procedure Committee will be headed by Dr. Bakhmeteff. Other members are: E. R. Kaiser (A.I.M.E.), Assistant Director of Research, Bituminous Coal Research, Inc., Oliver Bldg., Pittsburgh 22, Pa.; Herman Weisberg (A.S.M.E.); and Dr. C. G. Suits (A.I.E.E.).

Fourteen Research Projects Aided

Reports were made at the meeting on fourteen research projects sponsored and supported in part by Engineering Foundation during the past year. These projects, for the support of which nearly $500,000 was contributed by the Foundation and by industry, included research in such varied fields as the properties of riveted and bolted structures for bridges, properties of steel at various temperatures, properties of reinforced concrete for building construction, welding, lubrication and others.

Grants were recommended for the year



Another Christmas - -

and another New Year in the offing. Each new Christmas seems to have added significance—a deeper meaning—and it is because we are ending another year of pleasant association with those whose confidence and good will we value. The Holiday Season affords the opportunity to set aside business problems and we sincerely wish you a *Happy Christmas* and a successful and *Prosperous New Year.*

Pierre Champion

PRESIDENT

THE CHAMPION RIVET CO.

MAKERS OF CHAMPION WELDING ELECTRODES

CLEVELAND, OHIO —EAST CHICAGO, IND.

What's the right X-Ray film?

Product:
Pressure vessel
Material:
Cold rolled steel,
1-1/4 inches thick
Equipment:
200-kv x-ray unit

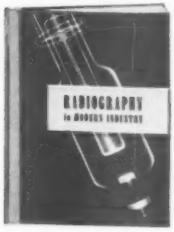
Remarks: RUSH

ANSWER:

KODAK INDUSTRIAL X-RAY FILM, TYPE K

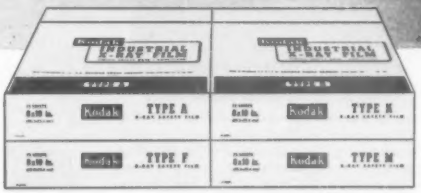
The wall of the tank was thick—the kilovoltage available was low. And the customer was impatient for delivery. So the radiographer did this job with Kodak Industrial X-ray Film, Type K.

This film, in contact with lead foil screens, has sufficiently high speed to allow reasonable exposure with equipment of moderate power. The good definition so obtained is added assurance that significant weld irregularities will not be missed.



RADIOGRAPHY IN MODERN INDUSTRY

A wealth of invaluable data on radiographic principles, practice, and technics. Profusely illustrated with photographs, colorful drawings, diagrams, and charts. Get your copy from your local x-ray dealer—price $3.00.



A TYPE OF FILM FOR EVERY PROBLEM

To provide the recording medium best suited to any combination of radiographic factors, Kodak produces four types of industrial x-ray film. They furnish the means to check welds efficiently and thus extend the use of the welding process.

Type K has medium contrast with high speed. For gamma ray and x-ray work where highest possible speed is needed at available kilovoltage without calcium tungstate screens.

Type F provides the highest available speed and contrast when exposed with calcium tungstate intensifying screens. Has wide latitude with either x-rays or gamma rays, exposed directly or with lead screens.

Type M provides maximum radiographic sensitivity, high contrast, and exceptional detail under direct exposure or with lead foil screens. It has extra fine grain and the speed is adequate for examination of light alloys at moderate kilovoltage and for much million-volt radiography.

Type A offers high contrast with about three times the speed of Type M, but with slightly more graininess. Used direct or with lead foil screens for study of light alloys at low voltages, and of heavy steel parts at 1000 kv.

Radiography...

another important function of photography

EASTMAN KODAK COMPANY
X-ray Division · Rochester 4, N. Y.

"Kodak" is a trade-mark

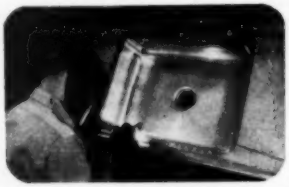
Kodak

How can you cut costs with ARC WELDING?

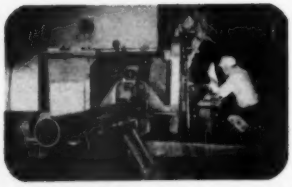
See this film and find out!

1. **"ARC WELDING AT WORK"**, a 16mm full-color motion picture produced by General Electric, has a message for every cost-conscious executive who may be overlooking opportunities for arc welding in his own plant. A vivid animated treatment (above)...

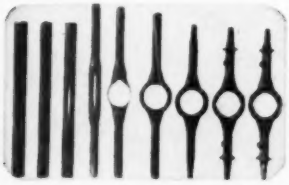
2...makes the technical parts of this film highly palatable. New uses for arc welding are suggested throughout. Welded building construction, for example (above) is shown to be efficient and economical. And as outdoor pressure vessels and piping...



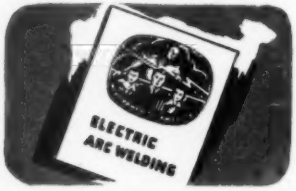
3...become larger and more complicated the value of modern arc welding becomes more and more evident. In fabricating a consumer product like kitchen sinks (above), the film shows how high-quality welding adds extra eye appeal and salability.



4. As exemplified in this tubing machine (above) automatic arc welding is shown to offer almost limitless opportunities. Here, precise heat control is the big factor. Also, arc welding provides highly ductile joints, a fabricating requirement for...



5...this automotive rear-axle housing (above). These welded joints withstand ten severe stretching and swaging operations, with no sign of failure! Because we believe you can profit from a wider knowledge of arc welding, let us send you this...



6. **ARC WELDING MANUAL . . . FREE!** It has all the data you need to make an intelligent decision on this vital subject. (The complete program consists of a 30-minute film, manual and "highlights" booklets.) MAIL THE COUPON TODAY!

FREE *to business management!*

General Electric Co., Section D684-13
Schenectady 5, N. Y. *Attach to your business letterhead*

☐ Please send me a complimentary copy of the G-E Arc Welding Manual (GES-3491). (Extra copies at regular manual price—$1.25.)

☐ I'd like to borrow a 16mm print of the color film from my nearest G-E office.

Name _____ Title _____

Company _____

Street _____

City _____ State _____

GENERAL ELECTRIC

1949–50 for the continuation of ten of the past year's fourteen projects and for the support of five new projects. Among the important new researches being undertaken with Foundation sponsorship and grants are the internal rusting of water pipes, the performance of power plant furnaces and increased efficiency in building small homes.

The Engineering Foundation, a department of United Engineering Trustees, Inc., has now been engaged in important research activities for more than 35 years. It aided in establishing the National Research Council and its division of Engineering and Industrial Research. It has contributed to the support of the Engineers' Council for Professional Development, which, representing some eight engineering organizations, aims at the advancement of the profession of engineering. "In the selection of research projects to be supported, preference has been given to those of a fundamental nature which would not be undertaken voluntarily by a single industry," Mr. Justin stated. "Where projects are of interest to a group of industries the Foundation has provided a limited financial support and a sponsorship intended to enable the principal support of the project to be secured from interested industries and other sources. It offers a well recognized and responsible channel for the fruitful expenditure of gifts and bequests, the income from which can be used to aid carefully chosen research projects."

Eutectic Celebrates New Plant Opening

Over 400 guests of Eutectic Welding Alloys Corp. attended the formal opening of the new Eutectic plant in Flushing, N. Y., on October 7th.

Prof. Otto H. Henry of Polytechnic Institute of Brooklyn was guest speaker and Rene D. Wasserman, president and founder of Eutectic, described the research and development program of the company.

The ceremonies were held in the plant's assembly hall, where many of the guests, representing leading industries, were given their first look at the recently announced training school, The Eutectic Welding Institute.

Highlight of the afternoon was a tour of the plant. Guests were shown the Laboratories, Foundry, Chemical Division, EutectoFilm Section and the giant high-speed extrusion presses of Eutectic's own design. At various points along the tour, welding booths were in actual operation to demonstrate the unique surface-alloying properties of five of Eutectic's most popular arc and torch rods. Interest centered around the new Eutec-Hand-Omatic, and hand-guided, no-arc-gap electrode for steel, which has only recently been made available to the public.

After the inaugural ceremonies, refreshments were served and an orchestra played for dancing.

GET 2 to 25 TIMES LONGER LIFE

with one of these 9 HAYNES hard-facing alloys

Protect metal parts from wear the economical way—by hard-facing them with a HAYNES alloy. These brief descriptions will help you select the right one for your wear problem.

HAYNES hard-facing alloys are easy to apply by all welding methods:

OXY-ACETYLENE

Smooth sound deposits can be made by both manual and automatic methods with HAYNES bare rods.

METALLIC ARC

Flux-coated rods, available in practically all grades, provide a steady, quiet arc

"HELIARC" WELDING

This new process provides another fast method for depositing HAYNES bare rods.

HAYNES STELLITE Cobalt-Base Alloys

HAYNES STELLITE Alloy Grade 1: The hardest of the cobalt-base alloys recommended for coating surfaces subjected to extreme abrasive wear and slight impact. It is especially useful for resisting heat or corrosion combined with abrasion.

HAYNES STELLITE Alloy Grade 6: The toughest and strongest of the cobalt-base alloys. Recommended for coating surfaces subjected to mechanical or thermal shock. Produces sound deposits that will not check or crack.

HAYNES STELLITE Alloy Grade 12: A hard, wear-resistant alloy that is tough enough to withstand shock and impact. Recommended for coating large areas where deposits free from checks or cracks are required.

HAYNES Iron-Base Alloys

HAYNES Alloy 90: Highly wear-resistant. Resists oxidation and retains much of its original hardness at temperatures up to 1,000 deg. F. Withstands moderate impact.

HAYNES Alloy 92: A moderately low melting point rod. Use it on thin sections where low-temperature deposition is necessary to prevent distortion and on large parts when preheating is difficult or impossible. Deposits have a hardness of Rockwell C 65.

HAYNES Alloy 93: Gives excellent service where high cold-hardness is necessary. It is suitable for applications involving abrasion from sand, gravel, mill scale, or other hard particles.

HASCROME Rod: A work-hardening rod, recommended for use under conditions of severe impact. It is widely used for hard-facing rock and earth handling equipment parts. Recommended for electric application to manganese steel.

HAYNES Tungsten-Base Alloys

HAYSTELLITE Cast Tungsten Carbide: The hardest of all HAYNES hard-facing alloys, used where utmost resistance to abrasion is required. Typical applications include oil-well drilling tools, ditcher teeth, and coal undercutter bits.

HAYNES Nickel-Base Alloys

HASTELLOY Alloy C: Recommended for building up wearing surfaces of hot-working steel mill parts such as hot shear blades, entry guides, and shafts.

HAYNES TRADE-MARK *alloys*

The trade-marks, "Haynes," "Haynes Stellite," "Hascrome," "Haystellite," "Hastelloy," and "Heliarc" distinguish products of Union Carbide and Carbon Corporation and its Units.

Haynes Stellite Company

Unit of Union Carbide and Carbon Corporation

UCC

General Offices and Works, Kokomo, Indiana

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Welded Design of Unique Diving Tower

Among its other unique and original features, the fabulous Shamrock Hotel in Houston, Tex., proudly points to its five- and ten-meter diving tower at its swimming pool. Its unusually graceful appearance results in a large measure from the extensive use of tubular material in the design. According to its designer, Winfield A. McCracken, consulting engineer of Paddock Engineering Company of Texas, Houston, the tower would be impractical if it were not for the facility provided by arc welding in making clean, smooth joints in this type of material.

Architect was Wyatt C. Hedrick, Inc. and the fabricator of the diving tower was A-1 Welding, both of Houston, Tex.

The shaft consists of a 24 in. diameter $^1/_2$-in. wall steel pipe with a 1 in. by 2$^1/_2$ ft. bolt ring at the base. It is 37 ft. 8$^3/_4$ in. high and is topped with a stainless steel "ships lantern."

Cantilever platform supports are 12-in., 20.7-lb. channels, split and tapered to 6 in. at the outboard ends. These are butt welded to and flush with the sides of the shaft. Bridging strutts are 6-in. junior beams. The top platform is 20 ft. 8$^1/_2$ in. long and the bottom platform 17 ft. 5 in. Floor beams consist of two 2- by 2$^1/_2$-in. angles at approximateiy 4-ft. centers.

The stair treads are cast aluminum, stud bolted to the shaft and are finished with an 18-gage steel plate around their outside ends. Hand rails are 1$^1/_2$-, 1- and $^3/_4$-in. shelby tubing.

Courtesy, The Lincoln Electric Co., Cleveland, Ohio

All steel is coated by metalizing with aluminum.

National

Carbide

IN THE RED DRUM

EFFICIENT

ECONOMICAL

DEPENDABLE

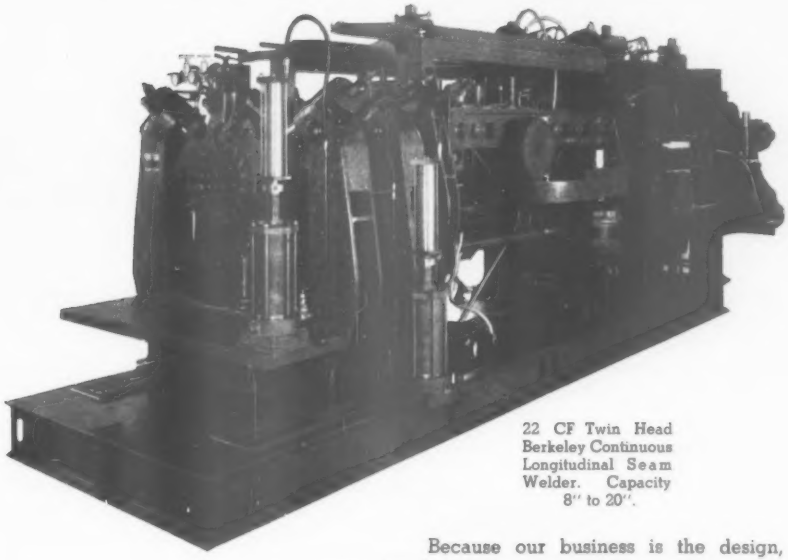
FOR WELDING and CUTTING

Use National Carbide in the Red Drum

Write us for information as to nearest available stock.

60 E. 42nd St. NATIONAL CARBIDE CORPORATION New York 17, N. Y.

STAYING OUT OF THE GROOVE IS OUR BUSINESS!



22 CF Twin Head Berkeley Continuous Longitudinal Seam Welder. Capacity 8" to 20".

Because our business is the design, engineering and manufacture of special jigs and fixtures, we can't afford to "get in the groove."

Manufacturers of:

- Continuous Longitudinal Seam Welders
- Horn Jigs
- Circumferential Seam Welders
- Boom Welders
- Turntables
- Head Setters
- Turning Rolls
- Universal Jib Welder

No two Penn Tool & Machine Co., products are alike because each of our customers has a unique requirement—a special problem to be met and solved by a welding jig or fixture.

But no matter how different one Penn Tool & Machine Co. product is from another, they all have the same sound design, practical engineering and superior operating efficiency that has characterized Penn products for many years.

If your production requires the welding of repetitive parts and your costs must be kept to a minimum, bring your problem to us. Our engineering skill, experience and modern plant facilities are at your disposal.

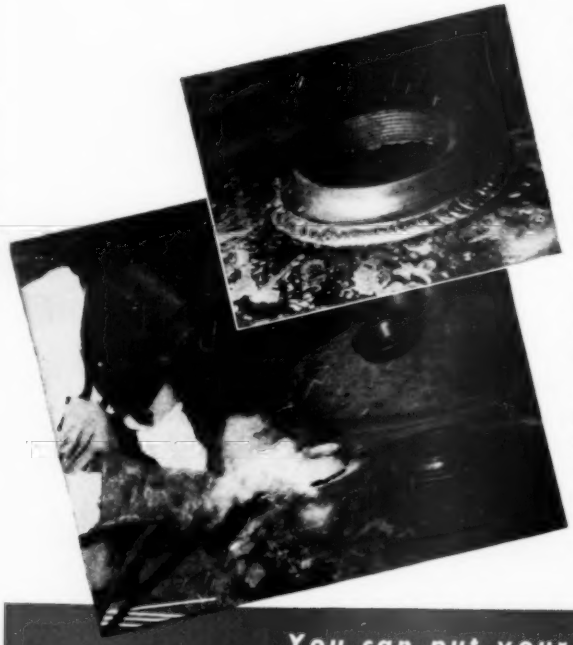
PENN TOOL & MACHINE CO.

An affiliate of THE BERKELEY EQUIPMENT CO.

DANVILLE ILLINOIS

ARC-WELDING FREE

FIRST sample our improved Class E-6010 electrode



G.E.'s NEW W-22 ELECTRODE (AWS Class E6010) is a reverse polarity d-c rod that produces high-quality welds in *all* positions. Its steady, spray-type arc is easily controlled . . . with little spatter, and excellent penetration.

This electrode is ideal for vertical and overhead welding jobs where welds of excellent appearance, high tensile strength, high ductility, and good impact resistance are particularly important.

The new W-22 has already proved itself in production tests . . . such as that at the Vulcan Steel Tank Company at Tulsa, where it was used in welding tank heads or end covers 36″ in diameter and ¼″ thick. Note the good fusion and excellent appearance of the finished welds. Their Welding Superintendent reports this electrode has the most forceful yet easily controlled arc he has ever seen.

You can put your confidence in

GENERAL ELECTRIC

ELECTRODES

combination offer

SECOND ...new G-E welding electrode comparator

GENERAL ELECTRIC WELDING ELECTRODE Comparator
ARC WELDERS • ELECTRODES • ACCESSORIES • RENEWAL PARTS
UNIVERSAL WELDING

Here's all the electrode comparison information heretofore available only on large, unwieldy charts—condensed into a handy, pocket-sized slide-rule. Naturally, it includes all G-E electrodes—mild-steel, special alloys, low-hydrogen, stainless-steel, hard-surfacing, etc.; and it covers the standard electrodes of all principal manufacturers—all suitably keyed to AWS classification numbers. And it's easy to use . . . just set the rule, and read off the comparison data directly. You'll find it the handiest means of comparing electrodes you've ever come across.

Clip the coupon for your free copy of the new G-E welding electrode "Comparator."

And here's a special bonus! Mail the coupon today, and we'll also send you a copy of the brand new edition of the pocket-sized G-E Arc-welding Electrode Catalog!

ARC WELDERS
ELECTRODES
ACCESSORIES • RENEWAL PARTS

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. . . or to Sect. A712-2, Apparatus Department, General Electric Co., Schenectady 5, N. Y.

Send me the following:

( ) Free sample of W-22 electrodes

( ) Welding Electrode Comparator slide rule

. . . and a copy of new electrode catalog, GEC-482

Name .....

Company .....

Address .....

City ..... State .....

PERSONNEL

Waidelich Made Vice-President

Election of A. T. Waidelich as vice-president in charge of research for The Austin Co., has been announced by George A. Bryant, president of the national engineering and construction firm. In this capacity, Waidelich will supervise the company's growing volume of plant location surveys and economic and engineering reports, as well as its independent research projects.

Waidelich joined the Austin organization as a structural designer in its New York district offices in 1936, and has been assistant director of research at the company's headquarters in Cleveland since 1941. He is credited with major responsibility for development of the revolutionary H-section welded truss, and directed more than a score of surveys and reports that have been the basis for postwar projects in which more than fifty million dollars has been invested.

A native of Philadelphia, Waidelich was graduated from Drexel Institute of Technology (B.S.-C.E.), and subsequently taught structural engineering at Massachusetts Institute of Technology, where he received his Master's Degree.

After traveling through Europe in 1930–31 on a fellowship from M.I.T., he joined the faculty of Robert College at Istanbul, Turkey, as assistant Professor of Civil Engineering, continuing in that post until he joined the Austin organization in 1936.

He is a member of the American Society of Civil Engineers, the American Concrete Institute, the National Society of Professional Engineers, the AMERICAN WELDING SOCIETY and Tau Beta Pi, and practices as a professional engineer in nine states.

Dash Wins Award

Edward Dash, 3014 Oregon Ave., Long Beach, Calif., welding engineer in the production department of the Long Beach Naval Shipyard, won a $1275 cash award, the largest ever presented to a Long Beach Naval Shipyard employee.

Dash developed a new procedure for welding aluminum alloy pins to aluminum bulkheads and fastening fiberglas insulation to the bulkheads. The Navy Department has affixed a $650,000 value to the estimated first year's savings to be obtained from Dash's suggestion.

Dash was born in Philadelphia in 1916. He was employed as a welding engineer at the Philadelphia Naval Yard from August 1940 until his transfer to Long Beach Naval Shipyard in May 1945. He is a member of the AMERICAN WELDING SOCIETY.

It was during his employment at the Philadelphia Naval Shipyard that Dash came upon the fiberglass insulation problem confronting the Navy and, although he does not consider himself necessarily of an inventive mind, the prize-winning suggestion came about as a result of constant concentration of the aluminum bulkhead problem.

Robert M. Curran Wins Award

In the recent R.W.M.A. prize contest, first prize of $300 for the best paper from a university source was won by R. M. Curran, P. Patriarca and W. F. Hess for their paper on "Optimum Flash Welding Conditions," which was published in the Research Supplement of the November 1948 issue of THE WELDING JOURNAL.

Robert M. Curran was graduated from the Rensselaer Polytechnic Institute with a degree of Bachelor of Science in Metallurgical Engineering in December 1942.

He was called to active duty with the U. S. Navy in February 1943 and received training in Naval Engineering at Columbia and Electronics at Harvard and M.I.T. Upon the completion of these courses he was assigned to duty aboard the U.S.S. Eldorado as Electronics Officer. While aboard this ship he participated in the amphibious assaults on Iwo Jima and Okinawa.

Upon release from active duty in early 1946, Mr. Curran returned to R.P.I. as a Research Fellow and continued graduate work leading to a Master of Science degree in Metallurgy in February 1947. Mr. Curran co-authored a paper "The Flash Welding of Structural Aluminum Alloys" presented to the AMERICAN WELDING SOCIETY in Chicago prior to the prize winning paper "Optimum Flash Welding Conditions" which was presented in Philadelphia last year.

Mr. Curran is a member of Sigma Xi, honorary engineering society, and the American Society for Metals as well as the AMERICAN WELDING SOCIETY.

Mr. Curran is now associated with the Schenectady Works Laboratory of the General Electric Co.

Wylie J. Childs Wins Award

In the recent R.W.M.A. prize contest, the second prize of $200 for the second best paper from a university source, was won by W. J. Childs, R. F. Underhill, Jr., and W. F. Hess for their paper, "Further Studies in Projection Welding" published in the Research Supplement of the January 1949 issue of THE WELDING JOURNAL.

Wylie J. Childs graduated from Rensselaer Polytechnic Institute in 1943 with the degree of Bachelor of Metallurgical Engineering. For the next five years he was a member of the staff of the Metallurgical Engineering Department of that school, concentrating primarily on welding research. He was awarded the degree of

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Metal-Arc	"131" Nickel Welding Electrode D.C.	For welding pure Nickel or "L" Nickel; and Nickel to steel
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Oxy-Acetylene	"42" Inconel Gas Welding Wire	For welding Inconel* using INCO "2" Gas Welding Flux
Metal-Arc	"132" Inconel Welding Electrode A.C.-D.C.	For welding Inconel; and Inconel to steel
Metal-Arc	"133" 80/20 Nickel-Chromium Welding Electrode A.C.-D.C.	For welding Inconel to steel
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Submerged Melt	"57" 70/30 Copper-Nickel Wire	For welding 70/30 Copper-Nickel

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Oxy-Acetylene	"44" "K" Monel Gas Welding Wire	For welding "K"* Monel, using 2 parts INCO "2" Gas Welding Flux and 1 part Lithium Fluoride
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Metal-Arc	"133" 80/20 Nickel-Chromium Welding Electrode A.C.-D.C.	For welding Inconel side only

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For further information, write for your copy of the catalogue: "INCO Welding Materials."

NICKEL INCO TRADE MARK ALLOYS

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Doctor of Philosophy in Metallurgy in June 1948. During the following year he taught and did research at the Massachusetts Institute of Technology. Dr. Childs has recently joined the staff of the Mining and Metallurgical Engineering Department at Lafayette College where he is teaching physical metallurgy and is in charge of the foundry education program.

Oehler Honored

A. G. Oehler, past-president of the AMERICAN WELDING SOCIETY, has been appointed a member of the Board of Directors of the United Engineering Trustees, Inc., representing the American Institute of Electrical Engineers, for a four-year term, beginning October 1949.

The United Engineering Trustees, Inc., is a corporate body representing the four Founder Societies in holding title to their joint physical properties: The Engineering Societies Building, the Engineering Societies Library, and trust funds for the Library, The Engineering Foundation, the John Fritz Medal Board of Award and the Daniel Guggenheim Medal Board of Award. The corporation also serves as treasurer for the Engineers' Council for Professional Development. The corporation manages the Engineering Societies Building, and has two principal departments, the Engineering Societies Library, and The Engineering Foundation. The corporate powers are vested in a board of twelve trustees, three from each Founder Society.

Alfred G. Oehler is electrical editor, *Railway Mechanical Engineer* and associate editor, *Railway Age*. Office: 30 Church St., New York.

Al was born in Lake Mills, Wis., Nov. 12, 1888. Married Sue Irma Converse, Dec. 25, 1917. He graduated from Univ. of Wisconsin with degree of B.S. in E.E. in 1911. Served in testing dept. Gen. Electric Co., 1911–13. Entered Railway Service with Northern Pacific Ry. as an electrician, serving in that capacity 1913–15 since when he has been: 1915–17, gen. foreman electrician, Wisconsin-Minn. Light & Power Co.; 1917–43, successively assoc. editor, managing editor and editor, *Ry. Elec. Engr.*; 1917 to date also assoc. editor, *Ry. Age*; 1943 to date, elec. editor, *Ry. Mechanical Engr.* (with which *Ry. Elec. Engr.* was combined). Ensign, U. S. Navy, 1918–19. Past-pres., A.W.S.; Fellow, A.I.E.E.; assoc. mem., Elec. Sec., Engrg. Div., A.A.R.; mem., Engrs. Club. Home address: 6 Liberty Place, Weehawken, N. J.

Haggerson Receives A.S.M. Medal

One of the country's top research honors went Oct. 20 to Fred H. Haggerson, President of Union Carbide and Carbon Corp., New York. The award, the 1949 Medal for the Advancement of Research, was presented at the annual banquet of the American Society for Metals.

Mr. Haggerson was cited as an outstanding example of an industrial leader who has advanced technological progress in broad fields of the metal industries to the ultimate benefit of the consuming public. In accepting the award, Mr. Haggerson paid tribute to the hundreds of people in Union Carbide's research laboratories, who, he said, were responsible for the achievements mentioned. He also praised industry for its research accomplishments, but said that the forces that made these achievements possible were not too well understood by the general public.

"Research, and I mean scientific industrial research, stems largely from privately endowed institutions and the laboratories of industry, both of which are a part of our free enterprise system—the American business system," he said. "The cost

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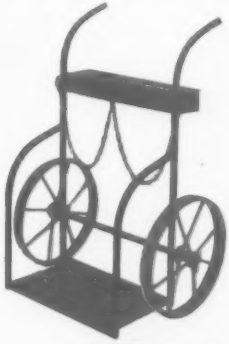

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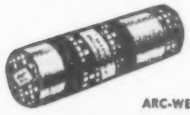

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could not be met nor the inspiration supplied without our free enterprise system. Industry spends millions and millions of dollars each year not only to support the work of thousands of research people but to pioneer in new fields and new ideas to assist in the competitive struggle with each other. Kill competition, which is also a part of the free enterprise system, and you will just as surely kill research. Kill research and you will kill any hope for a more abundant future."

The citation read at the dinner stated that Mr. Haggerson has been an outstanding example of the modern executive in a manufacturing enterprise, employing industrial research as an effective aid in the achievement of commendable business objectives. A considerable part of this research has been metallurgical in nature, dealing with new alloys and their properties, alloying and accessory steelmaking materials, as well as welding methods and the application of oxygen and acetylene in steelmaking.

Mr. Haggerson has been associated with Union Carbide and Carbon Corp. for 30 years, and was elected president of the Corporation in 1944. He is the seventh industrial leader to receive the Medal for the Advancement of Research since it was established in 1943.

Obituary

Mrs. Hazel M. Hakalow

Mrs. Hazel M. Hakalow, president and owner of General Welding Co., 2134 Twentieth St., Detroit 16, Mich., died in the S.S. Noronic fire at Toronto on Sept. 17, 1949. Mrs. Hakalow was the only woman member of THE AMERICAN WELDING SOCIETY Detroit Section and besides being active in all A.W.S. affairs was Chairman of the Patron Committee before her death.

Schnee Named Director

Verne H. Schnee, formerly assistant director of the Battelle Memorial Institute, has been named director of the University of Oklahoma Research Institute in Norman.

A graduate in chemistry from Cornell University, Schnee is the first full-time chairman of the OU Institute. During World War II he was chairman of the products research division of the war metallurgy committee of the National Research Council. Later he was appointed chairman of the committee on ship construction of the division of engineering.

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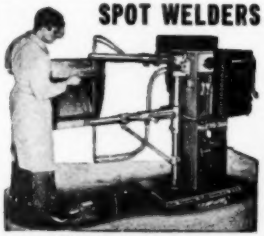

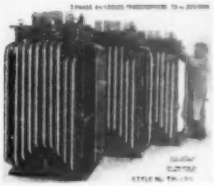

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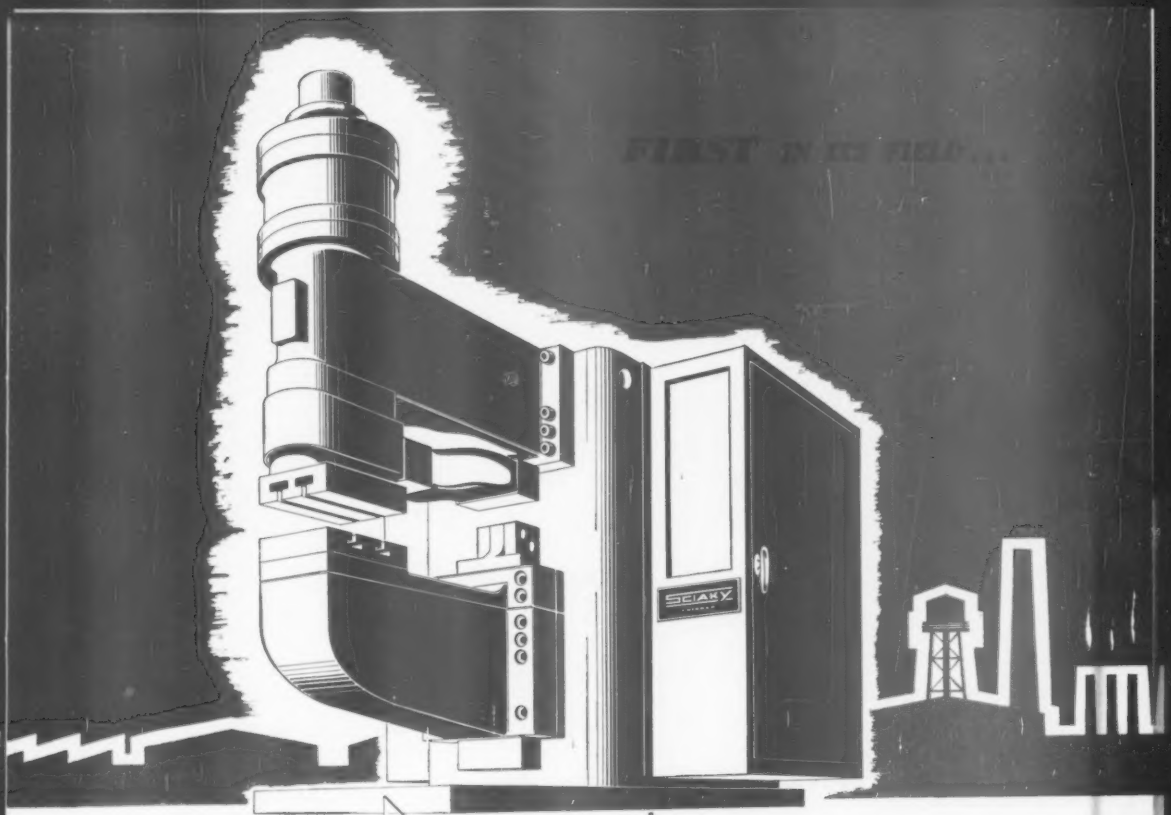

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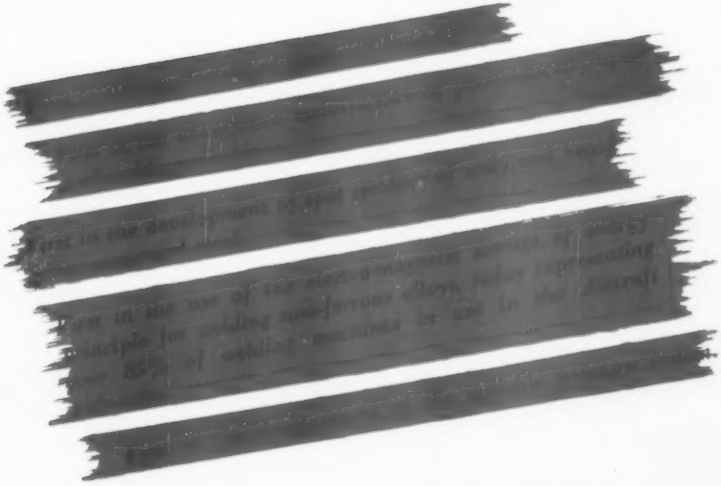

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NEW LITERATURE

Ultrasonic Reflectoscope

Bulletin 50-105 describing the Type UR Reflectoscope has been announced by Sperry Products, Inc., Danbury, Conn.

The Reflectoscope is an ultrasonic instrument for instantaneously locating defects in metals and other materials by the application of a single "searching unit."

Please address inquiries to E. B. Lang, Adv. Mgr.

The Miracle of Calcium Carbide Now Available

National Carbide Corp. has announced the publication of a 16-page booklet entitled, *The Miracle of Calcium Carbide*.

The booklet traces the history of calcium carbide from the time of its discovery as a commercial possibility over 50 years ago, through the developments of manufacture and the current and potential usage of commercial calcium carbide, acetylene gas and calcium hydrate residue.

The booklet points out that calcium carbide gas—acetylene—was first prominent as an illuminating gas, then assumed prominence as a fuel gas for the welding and cutting of metals, and in recent years has become an important raw material used in the manufacture of plastics and synthetic rubbers. Potential uses of calcium carbide as an industrial chemical reagent and of by-product calcium hydrate as a source of high calcium line are described.

Copies of this new booklet are available on request by writing National Carbide Corp., Rm. 1656, 60 E. 42nd St., New York 17, N. Y.

Weld Design

Weld Design, by Harry D. Churchill, Case Institute of Technology, and John B. Austin, Republic Structural Iron Works, published by Prentice-Hall, Inc., 70 Fifth Ave., New York 11, N. Y. Price $6.65. 216 pages.

Weld Design is intended to supply a definite need for a concise volume on welded machine-base design. Machine-design textbooks have thoroughly described the design of cast-machine bases, but very little information has been available with regard to the welded type of base. The reason for this situation is, of course, that electric arc welding is a production tool that only in recent years has been developed to the point, both metallurgically and in a manufacturing sense, where it has been generally recognized by the machine designer. Many engineers are aware of these advances but in many instances are unable to proceed because of a lack of welding information.

Pressure Vessel Accessories

Complete engineering data and specification details on Lenape pressure vessel accessories are included in the new 64-page Catalog 9-49 now available from Lenape Hydraulic Pressing and Forging Co., West Chester, Pa.

Sectionalized for easy reference, the company's line of welding necks, manways, nozzles, covers, rings, studding outlets, saddles, fittings, and other press-formed specialties is factually presented with complete dimensional data, pressure ratings, code specifications, construction details and service recommendations.

Illustration of all products, both in photograph and blueprint style are provided, together with installations and applications pertinent to the advantageous use of each item.

Also included is a handbook reference section of technical information for use by design and fabricating engineers.

A copy will be sent upon request to Lenape Hydraulic Pressing and Forging Co., P. O. Box 113, West Chester, Pa.

Aircomatic Folder

Air Reduction, manufacturers of industrial gases and welding equipment, have announced the publication of a new descriptive folder on the recently introduced Aircomatic welding process.

The illustrated folder tells the Aircomatic story in a concise manner, covering such topics as operation, features of the process, manual and automatic equipment. The illustrations include photographs of work done with this new process.

For your copy of this folder write the Airco sales office nearest you or Air Reduction, 60 E. 42nd St., New York 17, N. Y.

Heliwelding Booklet

Air Reduction, manufacturers of industrial gases and welding equipment, have announced the publication of a 16-page descriptive booklet on Heliwelding, an inert-gas-shielded arc-welding process.

Illustrated with more than 25 photographs, sketches and tables, the new booklet explains the process and when to use it, with such section headings as "Heliwelding Joins the Hard-to-Weld Metals" and "How Current and Polarity Affect the Weld."

The booklet also contains sections on equipment for manual, semiautomatic and automatic operation; a new automatic filler-wire feeder, and power supply equipment.

Copies may be obtained without charge by contacting your nearest Airco sales office or writing Air Reduction, 60 E. 42nd St., New York 17, N. Y.

Book on Magnesium

A new book published by the American Society of Metals, *The Story of Magnesium*, by W. H. Gross, will fill the gap in the libraries of engineer, metallurgist, professional and nonprofessional students.

The volume is designed for the layman rather than the scientific or technical specialist. It tells the story of a metal that, prior to the war, was merely a by-product of the chemical industry; American industry using no more than seven tons daily. During World War II the need for this lightest of all metals caused the government to build plants capable of producing 300,000 tons per year.

The Story of Magnesium tells of the methods of making this metal from salt water of the properties of the metal and its alloys and of the processes whereby the ingots can be converted into washing machines, vacuum sweepers and hundreds of other forms. There are chapters on welding and finishing, on forging and casting of this metal and a study of its production and uses.

The world need never fear a shortage of raw materials required to produce magnesium. In fact they can be considered inexhaustible. Actually, magnesium constitutes 2½% of the earth's crust which makes it the sixth most abundant chemical element. The most important raw materials available for the production of magnesium are salt water, naturally occurring underground brines and the common rocks, magnesite and dolomite.

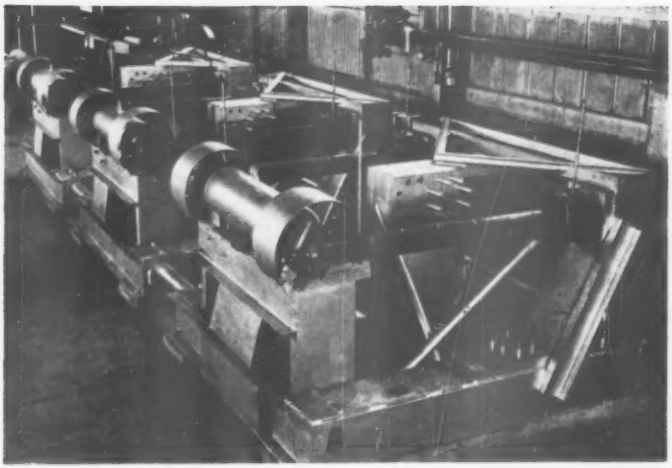
The Story of Magnesium, contains 262 pages, size 5¼ by 7¾ in., with 100 illustrations, printed on coated paper. It is available at $2.00 per copy from the American Society for Metals, 7301 Euclid Ave., Cleveland, Ohio.

Unionmelt Apparatus Catalog

A new 36-page booklet, *Unionmelt Apparatus Catalog*, has just been published by The Linde Air Products Co., a Unit of Union Carbide and Carbon Corp. It contains latest information on Unionmelt apparatus and supplies for submerged melt welding. Sections added include the portable DS Welding Head, the Shape Welding Carriage and the Flexible Welder. These welding machines together with new welding rods and new grades of Unionmelt compositions have all been developed since the previous edition of the catalog was published. There is also a section on the rebuilding of worn surfaces. Tables of recommended materials and procedures for this type of work are included.

Photographs of typical installations show the scope of the work that can be done with each type of apparatus. Part numbers are given for identification of complete machines and for those assemblies and accessories most frequently ordered.

This 36-page booklet can be obtained without charge from The Linde Air Products Co., 30 E. 42nd St., New York 17, N. Y.



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Other piping assemblies, too—welding elbows, mitre bends, manufactured and fabricated tees, pipe bends—have been subjected to punishment more severe than any they would probably face in normal service.

And this perpetual search for greater strength through better design has paid off in the form of realistic, non-theoretical facts providing a sound basis for Tube Turns' manufacturing policies—facts important to anyone interested in getting his money's worth in long life from piping installations.

Tube Turns' research and development organization, finest in the welding fittings industry, is constantly striving for the improvement of present products, the development of new ones. Notable among their recent achievements have been the design of a new type welding tee and the development of aluminum welding flanges.

Ask to be put on the mailing list for Tube Turns' technical periodical, *Piping Engineering*. Paper 6.01, for instance, deals extensively with standard steel flanges. Others give you research findings and additional working information pertaining to piping not generally available in convenient form.

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Eccentric crank arm produces up-and-down movement which creates a cyclic bending moment on flange or fitting at opposite end of assembly.

Water spurts from crack in test specimen. Almost invariably, failure occurred in the pipe adjacent to the flange.

Aluminum welding flanges . . . another Tube Turns first! Available in a wide range of types and sizes.

Monograph Descriptive Booklet

Air Reduction, manufacturers of industrial gases and welding equipment, have announced the publication of an 8 page, two-color, descriptive booklet on their new low-priced, portable, shape-cutting machine, the Airco No. 3 Monograph.

The profusely illustrated booklet covers in considerable detail the various features of this unique oxyacetylene shape-cutting machine. Four pages are devoted to "case histories" of actual production work done by the machine in field trial situations. An additional four pages are devoted to operating characteristics and design features of the machine.

For a free copy of the Airco No. 3 Monograph booklet, write your nearest Airco office or Air Reduction, 60 E. 42nd. St., New York 17, N. Y.

Manual of Spectroscopy

This book, by Theodore A. Cutting, has been written to assist those who wish to analyze ores, minerals, alloys and inorganic chemicals. In the qualitative analysis of such materials there is nothing so rapid and certain as a spectroscopic test within limits. The same is true of quantitative analysis. Although speed comes only after some experience, one may very soon acquire the necessary technique for accurate determinations.

The author has attempted to point out some of the short cuts to quick spectroscopic success. Direct methods of burning samples are discussed; the key lines of each element have been selected; and a new chart table has been prepared which shows both the spacing of spectral lines and their wave lengths. An increasing number of schools and universities are giving courses in spectroscopy, and many industrial plants are installing spectrographic equipment to speed their special problems of analysis. They will all find this book very helpful in their work.

One of the most valuable features of the book is the section on the determination of the elements. Here the author gives the strongest visible lines of each element, together with neighboring strong lines of common elements which can be used to locate them. This information is based on practical experience of the author and should prove of great assistance in visual methods.

Handling, Storing and Transporting Aluminium and Its Alloys

In this new edition of *Information Bulletin No. 15* the subject has been treated so as to broaden its application to suit the many and varied uses of aluminium today. After a description of the characteristics of the materials in relation to general conditions of handling, storing or transport, these subjects are treated in turn; and in its logical place between handling and storing, there is a section on methods of protection such as by greases and oils, strip lacquers and painting. Brief concluding paragraphs deal with the important question of identifying stock (since aluminium and its alloys all have similar appearance) and with segregation of scrap in order to take full advantage of the high recovery value of aluminium base materials of specified composition.

Airco Machine Gas Cutting Slide-Chart Again Available

Air Reduction, manufacturers of industrial gases and welding equipment, have announced that their oxyacetylene machine gas cutting slide-chart, introduced in 1946, has been reprinted and is now available upon request.

The chart covers two of the most widely used cutting tips, the Style 124 and the high-speed Airco 45. The tips are available in 18 different sizes, and all are included in the chart.

By sliding the chart to the indicated tip number, oxygen and acetylene pressures, speed in inches per minute, gas consumption and approximate width of kerf are all easily read down one column. Cleaning drill sizes are also indicated.

The chart is a pocket-sized $2^3/_4$ x 7 in. and can be comfortably carried in shop coat or overalls. Made of sturdy, 6-ply Toughcheck, it is reinforced with four metal eyelets and coated with a special long-wearing varnish.

For your free copy of the Airco machine gas cutting slide-chart (Form ADI 867), write Air Reduction, 60 E. 42nd St., New York 17, N. Y., or the Airco sales office nearest you.

Employment Service Bulletin

Services Available

A-585. Metallurgical Engineer desires permanent connection. Received B.S. in Chemical Engineering, 1936. Employed as metallurgist and chief radiographer, Worthington Pump and Machinery Corp. Served in Navy and discharged as Lieutenant Commander, August 1946. Has operated consulting and laboratory service. Past one and a half years with the AMERICAN WELDING SOCIETY as Asst. Technical Secretary and Assistant Editor, Welding Handbook to be completed soon.

A-586. Welding Engineer. B.S. in Metallurgical Engineering, age 39. Thirteen years' experience with large steel fabricator, Bureau of Ships and Naval Shipyards in planning and directing welding research and developments, preparation of technical reports, specifications, procedure control and in supervising laboratory personnel in connection with design and fabrication of pressure vessels, piping, heavy weldments, ships machinery and structure.

A-587. Welding Engineer. Age 34, married. Graduate University of Pennsylvania. Ten years' welding engineering experience in two Naval Shipyards. Thoroughly familiar with weldability of ferrous and nonferrous alloys. Broad knowledge of production equipment, techniques and procedures associated with resistance welding, submerged arc welding, inert-gas arc welding, metallic arc welding, gas welding and various processes allied to welding. Conducted special weldability and procedure investigations. Consultant on welding problems. Well versed in writing equipment specifications and welding procedures. Desires responsible engineering position in manufacturing plant or in engineering sales field. Now located in Southern California in a Naval Shipyard being inactivated.

A-588. Welding Inspector, or testing laboratory man, available December 1. Fifteen years' experience refinery, pressure vessels, piping and boilers.

Buy "PROVEN FLUXES"

Years of GUARANTEED SATISFACTION

behind these GOOD

"ANTI-BORAX" FLUXES

Insist on them — Unequalled Quality

No. 1 Cast Iron Welding Flux
No. 2 Brazing Flux for Brass, Bronze, Steel, etc.
No. 4 Braz-Cast Flux for Bronze Welding Cast Iron
No. 5 & 8 Cast & Sheet Aluminum Fluxes
No. 9 Stainless Steel Welding Flux
No. 11 Tinning Compound
No. 16 Silver Solder Paste Flux

Mfg. By

ANTI-BORAX COMPOUND CO., INC.

Fort Wayne, Ind.

WELDING CONNECTORS

Saze System Welded Connection Units for welded assembly

Saze Units place in position and securely hold together structural parts to be welded.

As used in many welded structures they *eliminate all hole punching* producing an economical, rigid, safe and quickly erected structural frame.

"Write for 58 pg. Manual containing full engineering design information for welded structures."

J. H. Williams & Company
Buffalo 7, New York

G. D. Peters Company
Montreal 2, Canada
Canadian Representative

PAGE WELDING ELECTRODES AND GAS WELDING RODS

WELDING STAINLESS?

○

TO RESIST WHAT?

HEAT?
COLD?
IMPACT?
BENDING FATIGUE?
CORROSION?
WHAT KIND OF CORROSION?

○

NOW ONE MORE QUESTION:

Are you using the best electrode or rod for your purpose?

If you're not too sure, get in touch with your PAGE distributor. Either he knows or he can find out from the PAGE Field Service Man. And the PAGE distributor has a wide selection of Page-Allegheny Stainless Steel rods and electrodes, so that he can give you the one that will serve you best.

ACCO

Monessen, Pa., Atlanta, Chicago, Denver, Detroit, Los Angeles, New York, Philadelphia, Pittsburgh, Portland, San Francisco, Bridgeport, Conn.

PAGE STEEL AND WIRE DIVISION.
AMERICAN CHAIN & CABLE

TRADE MARK

Get in touch with your PAGE Distributor

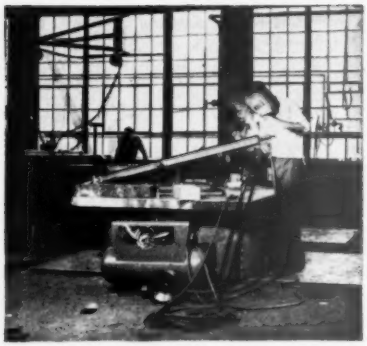
5 big G-E advantages

If you're welding with direct-current, General Electric D-C arc welders are designed with you in mind. Regardless of the job, they bring you:

1) Superior welding performance
2) Single-dial, dual control
3) 50% savings in size and weight
4) Easy, inexpensive maintenance
5) Dependable service over long "life span"

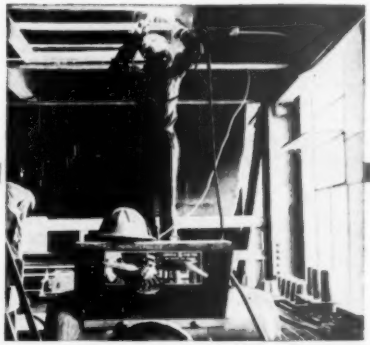
And finally, *G-E arc welder prices are now at their lowest point in ten years,* SO BY BUYING NOW YOU SAVE MONEY on the original purchase, welding operations, and maintenance. Your General Electric Welding Distributor can deliver just the model you want right from his own stock; don't put it off . . . call or write him today! *Apparatus Department, General Electric Company, Schenectady 5, N. Y.*

1



This G-E WD-42 200-amp welder is in constant use on a great variety of jobs in this welding job shop. Like the 300- and 400-amp models, it gives superior welding performance with a forceful, easily controlled arc over a wide current range.

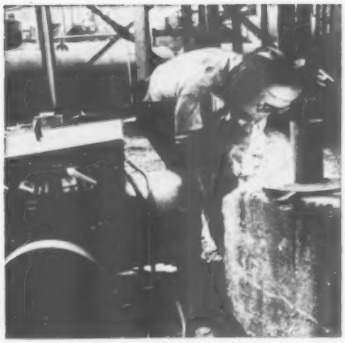
2



Here's one of 14 G-E d-c welders employed on a big power-plant construction job. Note the single-dial, dual control—it's standard on all three models. The handy electrode selector makes desired current settings easy, and gives complete flexibility.

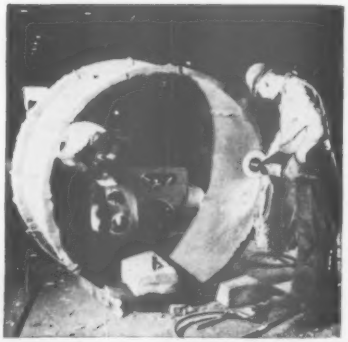
3

The 200-amp WD-42 welder is ideal for welding with low current on sheet-metal and other thin gauge materials. All WD-40 welders offer a 50% savings in size and weight over heavy, old-fashioned welders—thanks to efficient functional design, which has eliminated "dead-weight."



4

This WD-44 400-amp welder is a primary maintenance tool in the main generating station of a Massachusetts power company. And maintenance is simple and inexpensive on all G-E welders.

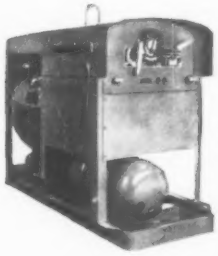


5

Plenty of heavy usage is the regular diet of this WD-43 300-amp welder in a New England foundry, and it's always ready for more; dependable service over a long "life-span" is one of its big features.

for 5 welding jobs

(and many more)

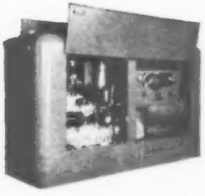


200-amp welder with Wisconsin air-cooled engine and V-belt drive; welding generator and control is identical to WD-42 motor-generator set. Also available with Hercules *liquid-cooled* engine. Note the auxiliary power take-off (d-c) for 110-v lights and universal tools. Approximate weight—1000 lbs.

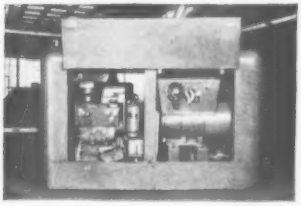
...engine-driven welders? Certainly!

In addition to the same advantages and welding characteristics of the motor-generator welders, G-E engine-driven welders also provide:

1. Easy, dependable operation with performance-proved engines.
2. Light weight, and a variety of trailer models, for ready portability.
3. G.E.'s "slow-down" control saves gas, and wear and tear by slowing the engine to idling speed when not actually welding; engine speeds up automatically the instant the arc is struck, with a precision governor to prevent overspeeding.
4. Engines operate at *constant* optimum speed; all welding control is electrical.
5. Muffled exhaust with rain cap to exclude water.



300- and 400-amp models are available with either 6-cylinder Chrysler gas-engine drive, or with. . .



. . . GM or Caterpillar diesel-engine drive. Electric starting is furnished on all 300- and 400-amp models, both gas and diesel, at no extra cost.

For light-duty welding this WD-3200BG 200-amp machine with air-cooled engine-drive is ideal; weighs only 660 pounds (net) and is only 26" wide.

You can put your confidence in— GENERAL ELECTRIC

711-9

ARC WELDERS • ELECTRODES • ACCESSORIES • RENEWAL PARTS

NEW PRODUCTS

Electronic Resistance Welding Control Equipment

Two new, all-electronic, high-speed resistance welding control equipments, for synchronous and nonsynchronous operation, are available from Westinghouse Electric Corp. The equipments have no moving parts in power and control circuits except initiation and solenoid relays, offering advantages in weld quality, welding costs and ease in which welds are produced.

Basic control panels consist of the plug-in Rectox rectifier tube firing panel (for nonsynchronous units) or a heat-control firing panel (for synchronous units). These basic controls include also the 3-B sequence weld timer, which controls squeeze time, weld time, hold time and off time for a single impulse spot welding. It provides nonsynchronous timing with repeat and nonrepeat control and nonbeat control. The substitution of a precision weld-time panel for a 3-B or 5-B sequence weld timer provides synchronous precision control when the heat-control panel is used.

These combinations are sufficient for many common resistance welding control requirements. However, space is also provided for the addition of auxiliary control panels to meet specific requirements. These auxiliary control panels, easily installed in the equipment, include a.-c. forge timer, d.-c. precision-type forge timer, wave-shape control, voltage compensator, initial-squeeze attachment, current regulator, temper sequence weld timer, dual weld attachment, interlocking relay attachment (enables use of one welding control with two welding machines), duel weld interval attachment, and a Timatic control attachment.

The cabinet housing this equipment provides ample room for installation and servicing the ignitron tube firing panel, the sequence weld timer panel, and auxiliary control panels, as required.

For further information write Westinghouse Electric Corp., P. O. Box 868, Pittsburgh 30, Pa.

New Magnetic Grounding Clamp

Dings Magnetic Separator Co., 4740 W. Electric Ave., Milwaukee 14, Wis., is now marketing the "MagnaGround," a permanent Alnico magnet designed to serve as a clamp for the ground cable of electric welders. Taking up to 600 amp., the MagnaGround is easily attached to the cable with setscrews or silver soldering, and is claimed to reduce amperage needed by providing a positive ground. The MagnaGround can be applied on any magnetic surface, vertical or horizontal, and the magnet will hold it fast. It can also be applied to nonmagnetic stainless by setting it on top of the work. Small, compact and powerful, this unit can also be used as a holding or welding fixture. Available through welding equipment dealers.

Dot-Weld Process

The Metallizing Company of America announces the new patented Dot-Weld process for reclaiming defective castings and repairing cracked castings and motor blocks. This revolutionary process is important to foundries and machine shops, as well as to salvage and motor block repair shops.

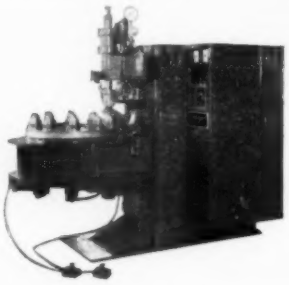
This method for depositing metal is a process which is entirely different from an other form of adding metal in that a fusion is attained without leaving hard spots. You can apply metal to a finished casting by the Dot-Weld Process without warping or distorting the parent metal. The Dot-Weld Process was developed for the salvage of defective castings which have small pinholes, voids and shrinks; for applying metals to mismachined surfaces; for the repair of cracked motor blocks, heads, and castings; for press-fit applications; for adding metal to patterns and for the preparation of hardened surfaces as a bond for sprayed metal.

The complete Dot-Weld and casting salvage installation cost, including 220-v. bonder, air filter and regulator, set of rotary files and an ME-1 peening hammer, is $589.75. The cost of a complete installation for a block repair station, including a 220-v. arc bonder, Moguloid Pistol, air filter regulator, mechanical kit and ME-1 peening hammer, is $518.

Further information may be obtained from the Metallizing Company of America, 3520 W. Carroll Ave., Chicago 7, Ill.

Merry-Go-Round Resistance Welding

How the magic of automatic dial feed mechanism can drastically cut man-hours and greatly increase quality.



The Sciaky standard welder employs an indexing mechanism to weld an electric motor housing composed of seven parts. These parts are loaded on a ten-station indexing table by hopper and magazine feeds and welded at the rate of 2000 units per hour. The table is ratchet actuated and is synchronized with the welder. Shaped mandrels mounted on the table serve as loading fixtures for parts other than those being welded. Where the automatic feeding is not practical, the piece parts are loaded by operators manually. The thicknesses of the parts welded are 0.017-, 0.023- and 0.029-in. cold-rolled steel. The completed unit, after welding, is automatically ejected into a receiving bin.

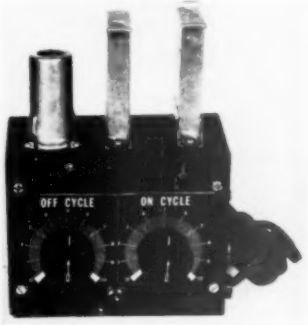
The Sciaky welder used for this job makes the 3-thickness weld on a power rating of only 100 kva. This is because it is equipped with exclusive Sciaky Three-Phase control—a feature which cuts current required 75% and draws a balanced load at 85% or better power factor.

The automatic nature of the machine's operation makes for higher and more consistent quality welds and positively accurate location of the piece parts. Once the optimum conditions are determined and set, these conditions must prevail for every weld.

Write to Sciaky Bros., Inc., 4915 W. 67th St., Chicago, Ill., for additional information on dial feed mechanism for your welding problems.

Cyclo-Flex Timer

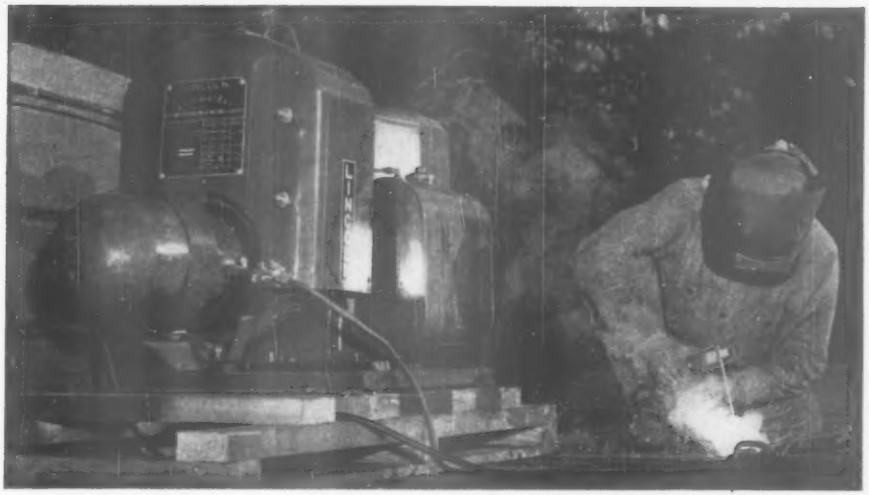
Description: The Cyclo-flex Timer is an electronic timer which may be operated either single interval with manual initiation, or as a repeat cycle timer with two adjustable intervals which occur successively without any external operation. Each interval is accompanied by relay contact closure and is obtained by the charging of a resistance-capacitance network. The timer intervals are virtually unaffected by variations in line voltage, temperature or humidity.



To convert from single interval to repeat cycle operation requires no change in wiring or additional equipment. It requires merely the rotation of the Off-Cycle control, clockwise, to the desired interval. The timer then operates as a repeat cycle timer. To convert back to single interval with manual initiation, the Off-Cycle con-

NEW ENGINE DRIVEN WELDER

Delivers 220 amps.... Only $375.00

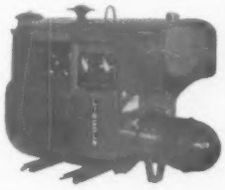


Compact, lightweight, the Lincoln DC-180 is ideal for field welding.

LINCOLN DC-180. Here's an amazing value in arc welders to simplify your welding and cut costs . . . an engine driven welder priced at only $375.00, *less than that often charged for a welding generator alone.*

Welding range is 20 to 220 amps., ample for the bulk of today's field welding and hardfacing work. Surprisingly economical on gas and oil. Powered by a dependable 13 HP. air-cooled engine with special controls for governing engine speed. No anti-freeze worries in the winter. Valuable as an extra pick-up unit. Weighs only 520 lbs. . . . can be mounted easily in any light delivery truck. Saves the cost and bother of moving heavier equipment on many jobs.

LINCOLN DC-200. Built for slightly heavier welding than the DC-180 arc welder. Price . . . only $450.00. Current range 30 to 250 amps. Has continuous current control for accurately setting the welding current. Weighs only 660 lbs. Powered by a 22 HP. air-cooled engine with automatic engine speed control. Can be provided with two-wheeled undercarriage for highway towing at slight extra cost.



Full details are available in free bulletins. Fill out and mail the attached coupon or write The Lincoln Electric Company, Dept. 912, Cleveland 1, Ohio.

The LINCOLN ELECTRIC Company

Largest Manufacturer of Arc Welding Equipment in the World

CLEVELAND 1, OHIO

Sales Offices and Field Service Shops in all principal cities

THE LINCOLN ELECTRIC COMPANY
Dept. 912, Cleveland 1, Ohio

Send full details at once on the ☐ DC-180 Engine Driven Welder, ☐ DC-200 Engine Driven Welder.

Name_____

Name of Company_____

Street Address_____

City_____ State_____

trol is rotated to zero. Provision is made for the connection of a foot switch or other contactor, for manual operation.

Ordering Information: Standard Cyclo-Flex is furnished with chassis mount. If totally enclosed housing is needed, please specify on order. Furnished information, is possible, as to time intervals for which use is proposed and use intended for timer.

G. C. Wilson and Co., 216 Passaic Ave., Chatham, N. J.

Reflectoscope

Functional changes in styling and external design, together with modifications which facilitate interpretation of test results are features of a new model of Reflectoscope—portable ultrasonic instrument for testing metals—announced by Sperry Products, Inc., Danbury, Conn.

Designated as Type UR, Style 50E351, the new instrument replaces the company's previous model, Type SR05.

Appearance of the Reflectoscope is modified by the use of a rectangular bezel to frame the oscilloscope screen, recessed controls and carrying handles, gray hammertone finish, and a removable bracket for holding the searching unit when not in use. The removable cover, which is held in place with a single catch, contains space for carrying all searching units and necessary cables. Molded rubber bumpers cover the corners of the instrument.

An improved pattern of square-wave "inch markers" on the horizontal axis of the screen facilitates interpretation of test results. Also, a new "Reject" control gives the operator additional control of sensitivity by rejecting indications of small defects which do not affect the performance of the part or material under test.

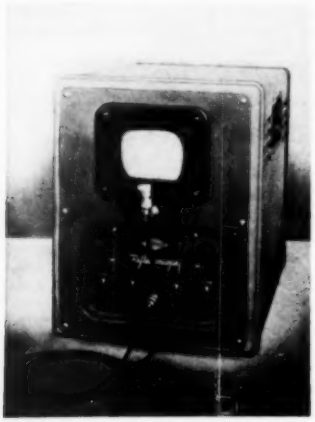
Principle and Operation of the Reflectoscope

Fundamentally, the Reflectoscope consists of a pulse-generator, *1*, used to generate short pulses of electrical energy at 0.5, 1.0, 2¼ or 5 mc., as required; a crystal transducer or "searching unit," *2*, used to convert the electrical energy into ultrasonic energy, and to couple this to the material under test. The searching unit also converts reflected ultrasonic energy into electrical energy and returns it to the amplifier, *3*, which increases the amplitude of the pulse sufficiently to cause an indication on the cathode-ray tube, *4*. A "sweep generator," *5*, is included to provide a time base for the cathode-ray tube and a "marker generator," *6*, produces a square-wave trace to furnish a measurement of distance.

The Reflectoscope transmits the pulsed ultrasonic vibrations into the material under test, at right angles to the surface, by means of the searching unit. When the vibrations are intercepted by a defect or reach the other side of the material, they are reflected back to the searching unit. The resulting indications on the cathode-ray tube indicate the start of the pulse and reflected vibrations. Their position on the horizontal axis, accurately locates the position of the defect in the material, in relation to the surface.

The Reflectoscope is used regularly in many plants for testing steel billets, forgings, castings, finished stock and a wide variety of machined parts including shafts, axles, rolls, piston rods, bolts and studs. Welds in steel plate, pipes and containers are tested by means of the angle-beam technique, in which ultrasonic vibrations enter and leave the tested material at an acute angle to the surface, and travel through the material by successive reflections between the surfaces.

Typical users of the Reflectoscope include steel mills, foundries, railroads, fabricators and processors of tool steels, aircraft and automotive manufacturers, metal working plants, ordnance plants, insurance companies and maintenance departments.

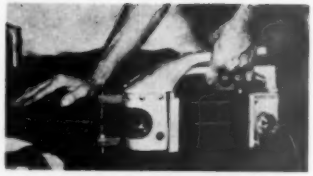


Portable Spot Welder

"Big Shot" is a portable spot welder which you take to the job instead of bringing the job to it. This affects new saving on manufacturing, assembly, installation or repair costs. The "Big Shot" welds quickly and efficiently like any big spot welder, up to the limits of its heat, 110-v. units weld readily two sheets of any weldable steel 20 to 18 gage, galvanized iron, Monel and Hoskins alloys, stainless steel 2 gages thicker. The 220-v. unit welds up to ⅛ in. thickness.

The portable spot welder is ideal for manufacturers, assembly and maintenance departments in industry; for installing; repair, body, tin, sheet metal, school and hobby shops; manufacturers of sheet metal products, toys, radios, television, stores, fixtures and many others. Its size, 4 x 4 x 15 in. and special rounded nose, top and sides makes it perfect for reaching, difficult places.

"Big Shot" is a light weight, 22-lb. portable unit which is operated with only one hand, leaving the other hand free to move and position the work. Because the operator's one hand is free to hold the work clamping devices are unnecessary. The unit is safe from shock. It is sufficiently heavily insulated to pass a test at 1600 v.



Tongs are square to prevent twisting out of position. They have twice the usual area, all of which makes for a fast, clean weld, with the square tongs meeting perfectly. Specifications are 3½-in. reach, 5-in. over-all; 6-in. reach, 7½-in. over-all; 12-in. reach, 13½-in. over-all.

For literature, prices and further information write: Tool and Equipment Distributors, 636 S. 10th Ave., La Grange, Ill.

Fabric-Walled Welding Booth

Vinyl-coated cloth woven of Fiberglas yarns is used for the four sides of a new welding booth in the main plant of Tube Turns, Inc., Louisville, Ky., manufacturer of welding fittings and flanges.

The cloth, known as Fibrylon, is suspended by hooks from a rod frame made to the size of the work area. The cloth is hung in overlapping panels, and easily pushes aside at any point to permit the entrance or removal of the pieces to be welded. It is weighted at the bottom to prevent flapping and clears the floor by about 1 in., allowing air to circulate freely and carry off fumes and heat.

The cloth is noncombustible and has high tear strength. It is, in addition, moisture proof, mildew resistant, cleanable, colorfast and durable, does not stretch or shrink and because of its inorganic composition, will not rot or decay. It is resistant to most acids and alkalies.

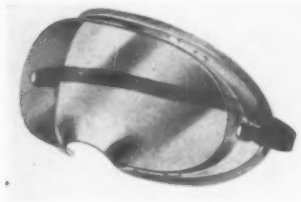
Advantages of the new booth are: Low cost, compared with metal enclosures of the same size; quick access from any angle; ability to receive large size work without difficulty; portability and more comfort for the welder.

Fibrylon is manufactured by The Holton Corp., New Orleans, La.

Lightweight Safety Goggle

A new safety goggle extremely light in weight but heavy in eye protection has been announced by the Chicago Eye Shield Co.

The goggle—the new lightweight Coverlite—weighs only $^{97}/_{100}$ of an ounce, with this negligible weight being distributed evenly over the nose, brow and cheeks. Workers say they are hardly aware of wearing the new Coverlite.



The new Coverlite is exceptionally sturdy. The injection molded, nonflammable plastic frame gives full protection from impact, dust, flying sparks and chips. Ample air space and ventilation prevents fogging while the large frontal area provides a wide range of vision in all directions. Another feature is the easy-to-adjust elastic headband.

Ideal for buffing, polishing, light assembly and spot welding, the new Coverlite is available in clear, light green or dark transparent frames. The new design also permits comfortable wear over most types of personal glasses without interference to the wearer.

For complete information on the new Coverlite goggle, write Chicago Eye Shield Co., 2300 Warren Blvd., Chicago 12, Ill.

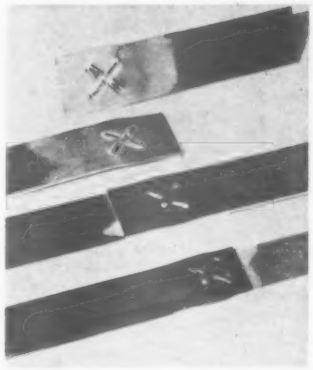
Cold Pressure Welding

The method of welding metals by pressure at room temperature or cold pressure welding has been developed by the General Electric Co., Ltd., of England. This process, controlled in the United States by the Koldweld Corp., William Dubilier, President, Suite 4408, 10 E. 40th St., New York 16, N. Y., can be successfully applied to several types of nonferrous metal—aluminum, duralumin, cadmium, lead, copper, nickel, zinc and silver. However, for the present its most important application probably is for the cold welding of aluminum. On ferrous metals experimental work is now progressing, but is not complete.

Preparation of Surface

The aluminum surfaces to be welded must be entirely free from the film of oxide which begins to form on aluminum immediately after it is exposed to atmosphere. Although thin by ordinary standards, this film will prevent welding, but it is easily removed by wire brushing.

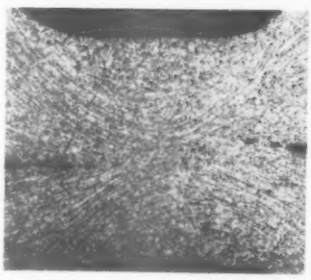
Once removed, the oxide film reforms comparatively slowly, and satisfactory welds can be made several hours later, provided that the cleaned surface has not meanwhile been contaminated by moisture or grease. Even the contamination caused by handling the material will invariably prevent formation of a satisfactory weld.



Strip joints of aluminum (center) and aluminum welded to copper (lower). Top pieces show where tear takes place

Pressure and Metals

In the cold pressure process of welding, the metal is made to flow away from the welding point as the tools are brought together. It is perhaps surprising that the rate of application of the pressure does not appear to affect the strength of the weld, and that good welds can be made with tools giving either a slow squeeze or an impact. However, the shape of the tool is most important. (Pressure of about 45,000 psi. is used for annealed aluminum.)



A micro-section of a typical Koldweld weld, showing the lines of flow. Note absence of weld line, a remarkable feature of this type of weld

From the runs so far carried out with suitable die materials, there has been very little evidence of die wear. In many applications, however, it will be possible to counteract the effects of such wear by occasionally resetting the die closure.

Hermetically sealed containers. Steps shown (left to right) are: Flanged tube before welding; after welding; excess metal trimmed off; weld dressed over

Applications of the Process

Three somewhat different techniques have been evolved—the straight weld, the ring weld and the continuous seam weld.

The straight weld can be used for box seams, for sealing tube ends and for other forms of lapped joints which are almost equivalent to butt welds.

The ring weld can be used for sealing the end of a flanged tube, and several other applications. It may be used for joining a flanged tube to a plate for making hose connections, or two disks may be joined together to form an air pressure cell. Wheels also may be constructed, by taking advantage of the natural flow of the material, to form the shape.

Among the important applications of the seam weld are those for tube-making and sheathed cables. A machine has been constructed in which the process of scratch-brushing, final forming, welding and trimming is carried out continuously and automatically. In addition, a roller welding machine can be used to seal the edges of a folded section while following quite a complicated outline. The free edges of a box-shaped section may also be seamed by rolling in such a machine.

Editorial Note: See also the February 1949 issue of THE WELDING JOURNAL.

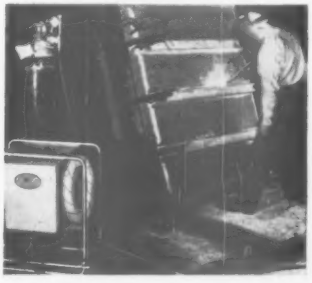
Aircomatic Process for Stainless Steel

When Air Reduction announced a year ago the development of the "Aircomatic" or inert-gas-shielded metallic arc-welding process for the welding of aluminum, there were strong hints that it would also be economically available for other metals before long. In the intervening year, the process has been successfully applied to the welding of chrome nickel or stainless steels and aluminum bronzes.

Briefly, the Aircomatic welding process revolves around the continuous feeding of a coiled wire electrode in a gaseous shield through the barrel of a welding gun. High-speed continuous deposition of filter metal is possible in all positions with a completely visible arc. Both manual and automatic equipment are available.

When applied to the welding of stainless, this process has certain specific advantages over the older and better known methods. For example, the filler metal is carried across the arc and deposited in the weld virtually without loss of alloying elements.

To illustrate, the Aircomatic transfers across the arc virtually 60% of the titan



ium that may be present. Existing metal arc welding methods lose almost all of it. This makes feasible the use of titanium stabilized filler metal rather than columbium stabilized—a factor of great importance should there be an international emergency.

The Aircomatic process also deposits more stainless steel at a given value of welding current and hence minimizes heat effects in the base metal.

The physical properties of the welded joint obtained equal and sometimes exceed those achieved by other methods. Superficially, the weld surface is dull, but it grinds, buffs and polishes to any desired finish as easily as welds made by other methods. The welds are sound, without porosity or slag inclusion, nor is there any slag to remove afterward.

Exceedingly high welding speeds are obtainable. When using $^1/_{16}$-in. wire (one of the standard sizes) deposition rates in the downhand position of 15 lb. per arc hour are possible. In addition, there is no stopping to change electrodes and no stub loss. Since $^3/_8$-in. thick square-edged plates can be welded without further edge preparation, by putting in only two passes—one from each side—there is a further saving in over-all fabrication costs.

Joint designs in heavy plates can be modified to have only a small included angle with large savings in welding material and time. Because only a fine wire, $^1/_{16}$ in. in diameter, must reach to the bottom of the weld groove, and since there is no slag to be trapped, the included angle may be reduced to 30°. The diameters of wire available are 0.035, 0.045 and $^1/_{16}$ in. in A.I.S.I. types: 310, 316 and 347.

At the present time the most popular method of applying aluminum bronze filler metal is to use coated stick electrodes. With these it is difficult to deposit porosity free welds when using the softer grades of this material. In the Aircomatic, we have a process that has deposited soundly aluminum bronze.

Both manual and machine units are in commercial operation. Delivery is dependent on the successful conclusion of the steel strike.

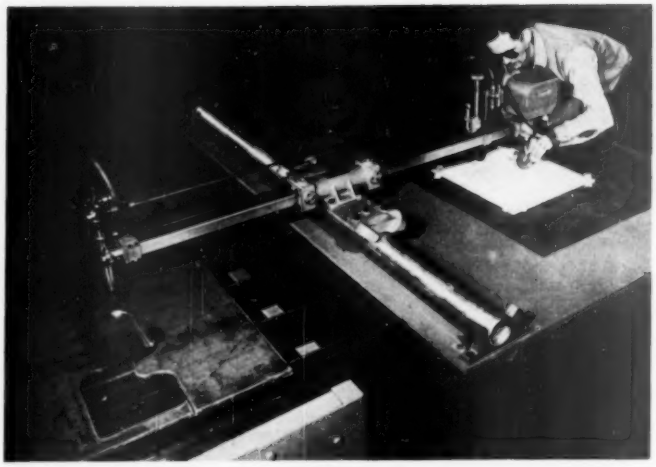
Prior to the introduction of the Aircomatic Process, it took Martin-Quaid 3 hr. to weld a 4 ft. $1^3/_4$ in. x 5-ft. aluminum tank side section with an inert-gas-shielded arc process. Using Aircomatic and hitting wire feed speeds up to 208 in. per minute, the welding time was reduced from 3 hr. to 15 min. Drawn aluminum wire, $^1/_{16}$ in. thick, was used. Current: 208 amp. d.c.

Monograph Shape-Cutting Machine

Air Reduction has announced the availability of a new portable, low-priced, oxyacetylene, shape-cutting machine, the Airco No. 3 Monograph.

According to Airco, the Monograph, which sells for $695, is the lowest-priced machine of its type on the market and brings machine gas cutting within the economic reach of thousands of shops which, up until now, have been unable to handle their own shape-cutting.

Operating Characteristics: The Monograph will cut steel up to 8 in. in thickness, in any shape within a 56 by 32 in. area, at speeds ranging from 3 to 30 in. per minute. The length of the cutting area can be extended by adding tubular rail extensions. This machine will also handle straight-line, circle and bevel cutting jobs with a high degree of accuracy.



The Airco No. 3 Monograph in action

Portability: The Monograph weighs only 110 lb., the tubular rail an additional 35 lb., making a truly portable machine that can easily be transported from shop to shop or to the work. The entire unit is packed in a sturdy carrying case that can be conveniently handled by two men and stored in a 7 by $1^1/_2$ ft. space.

Included in the $695 selling price is a manual tracing device, torch, tip, tubular rail, hose, straight edge, radius rod and carrying case.

Air Reduction is offering prospective customers the opportunity of trying out the Monograph in their own shop, on their own work. Details about this offer or descriptive literature about the machine may be obtained by contacting any Airco sales office or authorized dealer.

Power Brushing Reduces Costs of Weld Scale Removal

Through the use of power brushing for the removal of weld and heat scale The Caterpillar Tractor Co., Peoria, Ill., has been able to reduce the cost of preparing the surfaces of their products for painting.

A long-lasting protective paint finish depends primarily on a clean, well-prepared surface. This is done with brushes manufactured by the Osborn Mfg. Co., Cleveland.

Every metal fabricating plant has similar problems in surface preparation or weld cleaning. By using the Osborn Disk Center Wire Wheel Brush (Fig. 1) and the Osborn Wire Cup Brush (Fig. 2) Caterpillar Tractor is getting the lowest possible end-of-service cost. These brushes are run on portable air tools.

Prior to switching to power brushes, Caterpillar used several different methods of metal cleaning, but they found that Osborn Brushes do a cleaner job.

Fig. 1 The Osborn Wire Cup Brush made of 0.035 Wire gives long service and good operation for removing scale.

Fig. 2 The Osborn Disc Wire Wheel Brush make of 0.014 wire is effective in getting into joints and bends

abstracts of
CURRENT WELDING PATENTS

prepared by V. L. Oldham

Printed copies of patents may be obtained for 25¢ from the Commissioner of Patents, Washington 10, D. C.

2,482,937—Flame Hardening of Internal Cylindrical Surfaces—Robert M. Rooke, Long Branch, N. J., assignor to Air Reduction Co., Inc., New York, N. Y.

This novel flame-hardening process comprises directing a plurality of radially disposed heating flames against a substantially horizontally disposed circumferential portion of a cylindrical surface. These flames are moved vertically and upwardly along the surface and the heated surface is quenched immediately after the heating flames have been removed. A pool of quenching liquid is maintained in contact with the cylindrical surface below the heating flames.

2,482,945—Method of Flame Hardening—Stephen Smith, Jersey City, N. J., assignor to Air Reduction Co., Inc., New York, N. Y.

Smith's method relates to that disclosed in patent No. 2,482,937 and particularly is directed to the treatment of a hardenable ferrous alloy. One additional step in this method is to precool the cylindrical surface to a substantially uniform temperature prior to the flame hardening.

2,483,294—Acetylene Cutting Torch and Guide—James B. Miner, Portland, Ore.

A specialized type of a cutting torch guide device is disclosed in this patent.

2,483,454 — Method of Resistance Welding Finned Tubes—John W. Brown, Jr., Elyria, Ohio, assignor to Brown Fintube Co., Elyria, Ohio, a corporation of Ohio.

This specialized welding method comprises inserting a diametrically positioned fin in a partially expanded tube with such fin retaining the tube in partially expanded condition after the distorting force is removed from the tube. Electrodes are brought into engagement with the outer surface of the tube in alignment with the internally positioned fin and a welding current is passed between the electrodes to weld the fin in place.

2,483,477—Surface Hardening of Ferrous Metal Articles—Albert Edward Shorter, Sheffield, England, assignor to The Linde Air Products Co., New York, N.Y., a corporation of Ohio.

In this hardening method, the heated article is dropped into a tank of quenching liquid having a stream of such liquids moving lengthwise of the tank toward the point of removal of quenched articles. The stream of quenching liquid is moving at such a velocity as to tumble the quenched article within the tank and push the article toward the point of removal of the article from the tank.

2,483,545 — Welding Torch Attachment—Everett C. Johnson, Chicago, Ill.

Johnson's attachment comprises a flexible tubular fitting which is adapted to be detachably attached to the tip of a welding torch. A burner tube having an air inlet port therein is secured to the flexible tubular fitting by an intermediate interconnecting member.

2,483,691—Condenser Welding System—John W. Dawson, Auburndale, Mass., assignor to Raytheon Mfg. Co., Newton, Mass., a corporation of Delaware.

This welding control system includes a condenser which is charged by a direct current source which includes a rectifying space discharge tube that has a control electrode, the voltage of which controls the starting of discharge through the tube for each alternating current cycle. A second alternating current, displaced in phase from the first voltage referred to, is also impressed on the electrode. The condenser is discharged through a load circuit to supply a pulse of current thereto.

2,483,742—Torch Tip—Oliver Thurman, Jr., Mountain Lakes, N.J., assignor to Air Reduction Co., Inc., a corporation of New York.

This novel torch tip is of the block type and has slot-type jet passages therein. Metering ports are provided to connect the jet passages with gas distributing chambers formed in the torch tip.

2,483,957 — Welding Guide — Ben W. Wright, Boonton, N. J., assignor to Curtiss-Wright Corp., a corporation of Delaware.

In this patent, a fixture is provided for an elongated article so that the article may move laterally during a longitudinal welding pass under the influence of thermal expansion and contraction.

2,483,973—Apparatus for Welding the Seams of Tubular Articles—Walter J. Goettings, Greenfield, Wis., assignor to Chain Belt Co., Milwaukee, Wis., a corporation of Wisconsin.

This apparatus includes an inductor heating coil having a double loop portion arranged to have three parallel vertically aligned leg portions. The upper leg portions are spaced apart to permit a cylindrical metal workpiece to be inserted therebetween and the lower leg portion of the coil is arranged so that it is contiguous to the opposite inner curved portion of the cylindrical workpiece.

2,484,155—Arc Welding with Controlled Current Pulses—Lester D. Drugmand, Greenfield, Wis., assignor to Cutler-Hammer, Inc., Milwaukee, Wis., a corporation of Delaware.

The welding system of this patent includes an electron tube which has a main discharge path through an arc gap and which tube also has a control electrode. The cathode of the electron tube and the arc gap provide for ionization of the arc gap as a function of current flow between the control electrode and the cathode. Means are provided for impressing a pulse of ignition energy upon the circuit between the control electrode and the cathode to initiate the flow of welding current through the arc gap and associated means.

2,484,333—Commutator Brazing Fixture—Carroll F. Cobb and Joseph J. DeWindt, Silverton, and Stephen A. Weitlauf, Cincinnati, Ohio, assignors to Allis-Chalmers Mfg. Co., Milwaukee, Wis., a corporation of Delaware.

A specialized fixture device of the type indicated is covered in this patent.

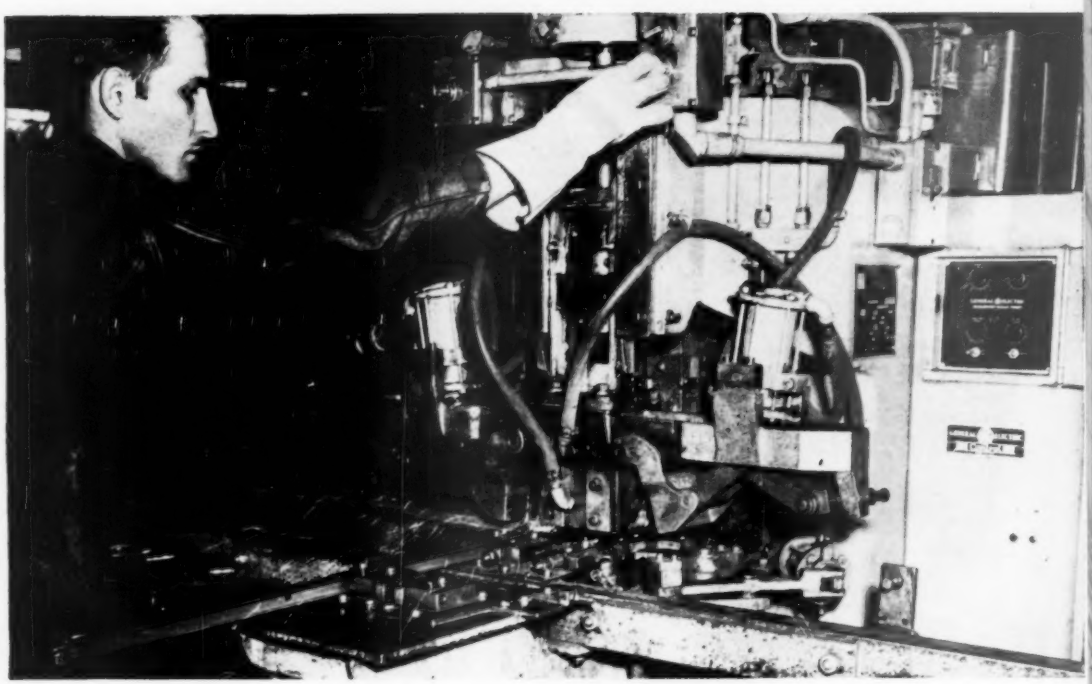
2,484,421—Electric Arc-Welding Apparatus—Mark T. Moore, Kearney, Nebr.

Moore's apparatus relates to an a.-c. electric arc circuit wherein an inductive-reactance is provided and has a coil with a core movable into and out of the coil. A transformer is provided and has one side of its secondary connected to one end of the coil and the other side of the secondary is grounded. A conducting member connects to the other end of the coil and means are present for adjusting the core into and out of the coil. A reversible rotary electric motor actuates the adjusting means and a normally open 2-way switch is provided for causing operation of the motor in the desired direction from a point remote to the inductive reactance. The switch is connected to provide the operating current for the motor from the secondary of the transformer by way of the coil of the reactance.

2,484,650—Induction Brazing Apparatus—Harold D. Ross, Jr., Oak Park, Ill., assignor to Western Electric Co., Inc., New York, N. Y., a corporation of New York.

G-E NONSYNCHRONOUS

Better than ever



All the control you need—including accessories—is contained in the modern attractive cabinet. Combines all the advantages of standard components with the specialized details and refinements required for your work. Nonsynchronous control is commonly required for welding standard steels such as are used for automobile bodies, stoves, furnaces, refrigerators, motors, etc. Here it is used for welding hinges to a steel window frame at Copco Steel and Engineering Company, Detroit, Michigan.

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G-E nonsynchronous control for resistance welders has been simplified, price reduced about 8 per cent.

Only *two* relays as compared to the previous *six* cut sequence time, mean faster operation. There is less wear, therefore, *less maintenance required*. The entire unit is more compact—*takes less space*. *Timing is now controlled electronically*.

General Electric development engineering and improved manufacturing methods have again resulted in lower prices, better operating methods for the user of resistance welders. This is an example of the continued efforts at General Electric to give you more precise control of this process. When you have resistance welding control problems, contact the nearest G-E sales engineer. You'll be sure of unbiased answers. You'll get the *right* control for the job. And when you order control specify General Electric.

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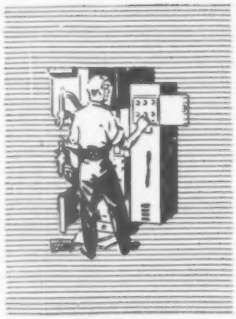
General Electric's More Power to America four-color, sound motion picture covering every phase of this manufacturing process. Contains tips for improved production for operators of machines, design engineers, and supervisors. Contact your Resistance Welder manufacturer, Power Supplier, or the nearest G-E office.



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compact, factory assembled unit may be mounted on the side of the machine, floor, nearby wall, or balcony as space permits.

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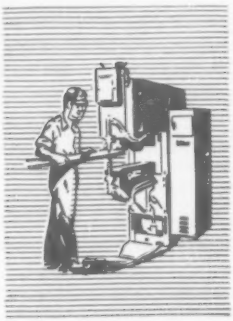
entire side of cabinet is a hinged door which opens to provide quick, easy servicing of circuit components, power tubes, and water system. ▶



• **EASY TO OPERATE—**
control station usually faces operator, but may be installed at the side of unit when mounted on machine, or may be separate from unit if remote control is desired.

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General Electric Co., Sec. A645-51
Schenectady, New York

Please send me supplement No. 1 Bulletin GEA-4726 on Nonsynchronous Welding Control.....

I would like a showing of "This is Resistance Welding".....

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.....

Ross' high-frequency heating device includes a loop of conducting material of tubular cross section which has a substantially cylindrical mass of conducting material within the loop. A central aperture is provided in the mass of material which is tapered toward the aperture to concentrate flux therein. A cup-shaped depression is coaxial with the aperture in the mass and means are provided for directing a protective atmosphere through such aperture in the mass of material.

2,484,868—Side Seam Container Electric Welding Machine—Wm. P. Winters, Cincinnati, Ohio, assignor to American Can Co., New York, N. Y., a corporation of New Jersey.

This machine is for electric butt welding a container body having opposed longitudinal side seam edges. The machine includes a mandrel on which the container body is positioned and which includes a movable support for engaging with the container body. A welding electrode is disclosed adjacent the mandrel and is adapted to press the side seam edges of the container body together to weld the edges along their entire length while in a compressed position.

2,484,959—Electric Welding Apparatus—Calvin Waldo Redekopp, Butterfield, Minn.

This electric welding apparatus includes a master switch controlling the operation of the apparatus and a variable resistance device is provided to control the amperage of the welding current output. A plurality of solenoids and variable-resistance devices are provided in the apparatus for controlling the output current of same.

2,484,973—Process of Welding Can Lock Seams with High-Frequency Current—Alfred Vang, Newark, N. J., assignor to Continental Can Co., Inc., New York, N. Y., a corporation of New York.

In this welding process for making cans, a lock seam is provided between opposite marginal end portions of a cylindrically bent can blank, the seam provides an externally open groove. A high-frequency welding current is passed between two close points on opposite sides of the groove on the exterior surface of the blank.

2,485,229—Welding Apparatus—Ernest Robert Workman, Chicago, Ill.

Workman's welding apparatus includes a transformer having primary and secondary winding and a primary circuit having a first relay means therein. This first relay has a timing means and an energizing coil and two pairs of contacts. One of these pairs of contacts is normally closed and in circuit with the primary circuit means whereas the other pair of contacts is normally open and associated with the energizing coil means of the first relay and with a source of supply current. The welding circuit is connected to the secondary of the transformer and has a second relay means therein. Special connecting means coordinate the actions of the two relay means of the apparatus.

2,485,357—Ferrule for Welding Studs—Albert M. Dancy, La Grange, Ill., assignor, by mesne assignments, to National Cylinder Gas Co., Chicago, Ill., a corporation of Delaware.

This welding ferrule has an upper edge with an inclined planar surface defined by a plane intersecting the welding ferrule intermediate its upper surface and a recess provided therein to facilitate automatic gripping of the ferrule by gripping means. This gripping action is facilitated by having relative rotation of the collar and gripping means after movement of the gripping means into registry with the recess formed in the ferrule.

2,485,360—Holder for Arc Welding and Arc Cutting of Metals—Rene D. Colinet, Philadelphia, Pa., assignor to La Soudure Electrique Autogene S. A., Brussels, Belgium.

This patent relates to an electrode holder for tubular electrodes wherein a gas connection is provided on the body of the electrode holder. A pair of cooperating gripping jaws are provided and are adapted to be swung toward a gas connection outlet for locking the jaws in position and also are operative by swinging the jaws away from the gas connection to release the jaws.

LIST OF NEW MEMBERS

October 1 to October 31, 1949

ARIZONA

Billie, W. H. (B)
Boan, B. M. (C)
Gieszl, W. J. (B)
Spillman, William J. (C)

BOSTON

Turck, Herbert (C)

BRIDGEPORT

Bontya, Ernest J. (D)

CHICAGO

Klemmer, Bruno H. (C)
Kopczyk, Frank (C)
Rondeau, Henry S. (C)

CINCINNATI

Mason, Frank John (D)
Nieman, John C. (C)
Poynter, Joseph S. (C)

CLEVELAND

Bernardi, William R. (C)
Black, Alex A. (C)
Boly, Roger W. (B)
Booth, Jack E. (C)
Konrad, Louis, Jr. (C)
Metzger, Raymond W.(C)
Olds, Milroy L. (C)
Rowlinson, Oscar C. (C)
Shirley, Wayne H. (C)
Sipe, Ray C. (C)

COLORADO

Geller, Herman (B)

COLUMBUS

Mathews, Donald (D)

DALLAS

Catina, Tony (B)
D'Auignon, Roy J. (C)
Gunthard, A. (B)
Irwin, William H. (B)
Mayes, Harold (B)
Reese, A. C. (C)
Weeks, Lloyd W. (B)

DAYTON

Brentlinger, Abram E. (D)
Hambrick, William L. (D)
Howell, William B. (C)
Petry, Howard J. (C)
Rehse, Frank H. (C)

DETROIT

Dwyer, Patrick R. (B)
Ginger, George L. (B)
Lewis, Frank (B)
Lohrer, Walter R. (C)
Martensen, L. T., Jr. (B)*
Van Flandern, R. F. (B)

EASTERN ILLINOIS

Alston, William W. (B)
Appel, Theodore B., Jr. (B)
Barrett, H. J. (B)
Berkeley, John (B)
Burmeister, Herbert (B)
Cowles, Fred (B)
Cummings, Paul (B)
Dawes, Lelan (B)
Depke, Herbert F. (B)
Gross, Verdys Leroy (B)
Hughes, A. E. (B)
Krobbe, Clarence J. (B)
Linn, Wayne E. (C)
Minyard, Dale P. (B)
Pearson, Ralph S. (C)
Servatius, Howard (B)
Shelato, Orville (B)
Smoot, Paul L. (B)
Thompson, Joseph Wilbur (B)
Thompson, Roy L. (B)
Vincent, Archie J. (B)
Walter, William R. Jr (C)
Young, Chester L. (B)

HARTFORD

Hellickson, A. G. (C)
Phillimore, Horace (C)

HOUSTON

Cargill, Clarence C. (B)
Shall, David L. (B)

INDIANA

Endicott, Carry W. (B)

KANSAS CITY

Blake, P. D. (C)

LONG BEACH

Butler, A. H., Jr. (C)
Thomas, R. W. (C)

LOS ANGELES

Alcock, Robert W. (C)
Templeton, J. E. (B)

MARYLAND

Barnitz, Fred S. (C)
Bilsecker, Frank, Jr. (B)

Brenner, James E. (B)
Campbell, Russell M. (B)
Coss, William C. (B)
Dorsey, Clarence T. (C)
Duffield, J. Walter (C)
Easter, Lyman F. (C)
King, Harry W. (C)
Motzenbecker, George E. (C)
Sheehan, John M. (C)
Staley, Mervin W. (C)
Stallings, B. L. (C)
Zinkand, William C. (C)

MILWAUKEE

Erickson, Melvin (B)
Nolan, C. A. (C)

NEW JERSEY

Donnelly, William F. (C)
Kornylak, Andrew (B)

NEW YORK

Fenton, Edward A. (C)
Landis, H. D., Jr. (B)
Miller, C. J. (B)

NIAGARA FRONTIER

Rich, Stuart L. (C).
Wiede, Richard W. (C)

NORTHERN NEW YORK

Winn, William, Jr (D)

NORTHWEST

Karna, O. J. (B)
Lowry, Robert K. (B)
Zagar, Rudolph S. (C)

NORTHWESTERN PA.

Allen, Robert K. (C)

OKLAHOMA CITY

Bache, Jack (C)*
Boeckman, George W. (C)
Cason, J. E. (C)*
Dilger, Verlin W. (D)
Henderson, Ralph (C)*
Lunn, John (C)*
Ryan, Jess (B)
Suhre, Fred H. (C)

PEORIA

Purcell, Keith L. (C)

PHILADELPHIA

Denney, Edwin, C., Jr. (B)

PITTSBURGH

Graham, D. W. (C)
Service, Murray G., Jr. (C)
Tisdale, Norman F. (C)

PORTLAND

Alden, R. M. (B)
Brunkow, W. D. (C)

ROCHESTER

Barr, Robert J. (C)
Hahn, Rea I. (B)

SAGINAW VALLEY

Berger, Barron (B)
Edwards, Stanley W. (C)

Falter, Thomas C. (D)
Kendall, Richard E. (D)
Moehring, Wilbur E. (C)
Rembold, Charles E. (D)
Snyders, Robert L. (C)

ST. LOUIS

Mathae, E. G. (C)

SALT LAKE CITY

Davenport, Orson H. (B)

SAN FRANCISCO

Byers, S. S. (B)

SYRACUSE

Fudesco, Frank R. (C)
Jones, Fred A. (B)
Mc Avoy, Leo W. (C)
Weart, Harry (B)

TULSA

Geppelt, Elmo Walter (C)

WASHINGTON

Robinson, John W., Jr. (C)

WESTERN MASS.

Tinsman, Joseph A. (C)

WESTERN MICH.

Pinkerton, Ray C. (C)
Van Uum, E. (C)
Wolsey, H. C. (C)
Wright, Andrew J. (C)

WICHITA

Hein, F. W. (C)
Horejsi, Earnest (C)
Phillips, J. T. (C)
Stauffer, Howard V. (C)
Tritchler, Wayne C. (C)
Van Horn, V. C. (C)

YORK—CENTRAL PA.

Pyle, Charles H. (C)
Quillen, J. P. (C)

NOT IN SECTIONS

Barreto, Domicio (B)
Christiansen, Paul B. (D)
Jurado, Gonazlo (B)
Parker, Marvin M. (C)

Members Reclassified

During the month of October

ANTHONY WAYNE

Johnson, Harry M. (C to B)

PHILADELPHIA

Raymo, Arthur J. (C to B)

ST. LOUIS

Jablonsky, R. D. (C to B)

SOCIETY

Singh, Pritam (C to B)

* September New Member

SECTION ACTIVITIES

Prepared by C. M. O'Leary

Anthony Wayne

The October meeting of the Anthony Wayne Section was held on Friday, Oct. 14, 1949, at the Fort Wayne Chamber of Commerce Bldg. Following a buffet dinner which started at 6:30 P.M., the members and their guests were feted to a half-hour program of both old and new barber shop songs presented by the Reddy Kilowatt Barbershop Quartet.

Kenneth Zimmerman, Program Chairman for this meeting, introduced R. T. Gillette of the General Electric Co., Schenectady, N. Y. Mr. Gillette was the main speaker of the evening. After showing a sound movie "Chain Welding by Resistance Welding," he presented a talk on Resistance Welding.

Mr. Gillette reviewed the history of this particular phase of welding from its innovation. He discussed methods, good procedure practice and proper design, with good illustrative slides to back up his arguments.

Information was given relative to electronic controls including the new "Slope Control." This new development enables the industry to do new types of resistance welding such as the projection welding of aluminum.

Following the talk, a discussion period was held in which a number of participants were able to ask questions and receive answers on their own problems. This part of the program was very educational and helpful.

There were 45 in attendance at the dinner and 50 at the technical session.

Arizona

The Arizona Section held its monthly meeting on October 19th at the Westward Ho Hotel. Forty-five members and guests were present.

The first speaker of the evening was August Rau, Vice-President and Chief Engineer of Allison Steel Co., Phoenix, Ariz., who gave a most interesting talk on arc welding of structural aluminum. Mr. Rau, who is also second Vice-Chairman of the Arizona Section, is very well qualified in this subject having spent a good many years during the war in the construction of pontoon bridges for the Army.

The second speaker of the evening was Dr. William A. Rhodes, Ph.D. (Honorary) who spoke on a.-c. welding. Dr. Rhodes gave an interesting and instructive description of the various types of a.-c. machines in use today. He dwelt particularly upon open-circuit voltages and their control.

Ralph A. Hoffman, Superintendent of Bridges for the State of Arizona, and Section Chairman, presided.

Birmingham

October dinner meeting of the Birmingham Section was held on the 6th at Hooper's Cafe.

The Section was fortunate to have as the principal speaker of the evening, Anton L. Schaeffler, Metallurgical Engineer, Arcos Corp., Philadelphia, Mr. Schaeffler discussed factors that the designer, welder and supervisor should consider in fabricating stainless, Monel, nickel and clad steels. He has had wide experience in metallurgy of alloy welding and is author of several papers on the subject. Mr. Schaeffler's talk was received with much interest.

Jerome J. Schlass, of the same company, has had wide experience in Field Engineering work, and answered many of the questions from the audience during the discussion period.

The above speakers personally demonstrated welding of stainless, Monel, nickel and clad steels, which were witnessed by a group of forty interested observers.

Boston

The Boston Section held its regular monthly dinner meeting for October on the 10th at the Graduate House, M.I.T., Cambridge, Mass. Dinner speaker was Arthur Forrest, Treasurer, Directing Manager of Norwood, Mass., Arena. Mr. Forrest gave an illustrated talk on "An Inside Glimpse of Stock Car Racing," which was very well received.

Technical speaker was Howard E. Van Valkenburg, Ultrasonic Research Engineer, Sperry Products Co., Danbury, Conn. He gave an illustrated lecture on "Testing with Ultrasonic Reflectoscope." The speaker very ably presented the development of ultrasonic inspection of welds.

P. J. Durney, Boston Section Technical Representative, gave a good talk to the members of the A.W.S. Codes, Standards and books

Cleveland

The River-Lake Belt Conveyor was the very interesting subject of the October 12th meeting held at the Cleveland Engineering Society. A. B. Smith of the American Bureau of Shipping was Technical Chairman. N. R. Michell, Vice-President of the Akron, Canton and Youngstown Railroad Co., presented the general story of the belt. Mr. Michell's discussion of the belt set forth the economic basis and the important part it will play in Great Lakes shipping as a link in the transportation chain of iron ore from the upper lakes to Inland Ohio and Ohio River valley steel centers. H. Wickenden, Engineer, Goodyear Tire & Rubber Co., substituting for E. W. Stephens, gave the engineering details. A film "Design for Arc Welding Structures" was shown in conjunction with the subject.

Coffee talk was given by J. M. Poe, an attorney, who spoke on one of his hobbies —the racing pigeon. Mr. Poe told many interesting stories about the pigeons at home and while competing in races.

This was a joint meeting with the Great Lakes Section of the Society of Naval Architects & Marine Engineers and had an attendance of 150.

Colorado

October dinner meeting of the Colorado Section was held on the 11th at Silver Wing Inn, Denver.

Technical speaker was L. E. Kunkler, President of Metallizing Company of America, who spoke on "Metallizing, Its Technique and Purpose." A film on the subject was also shown.

At the close of the meeting the group proceeded to the shop of Metallizing Specialties Co., where a very interesting practical demonstration of metallizing was given by Henry Engleman, Engineer for Metallizing Company of America. Refreshments were furnished by Les Erb and Bill Sherman, owners of the Metallizing Specialties.

Dallas

Technical meeting of the Dallas Section was held on October 19th in the Auditorium Mercantile National Bank. Dinner in the Town and Country Restaurant preceded the technical session.

Technical speaker was L. D. Sugg, Technical Engineer of Magnolia Airco Gas Products Co. His subject "Oxyacetylene Machine Shape Cutting" was illustrated with slides and a film. The speaker was well qualified in his subject; clear and precise in his answers to questions.

Dayton

A very interesting and informative lecture on "Stress Raisers and Their Significance in Welded Design," was presented at the October 26th meeting at the Dayton Engineer's Club. The speaker was Paul H. Setzler, Assistant Executive Engineer of the Lima-Hamilton Corporation of Hamilton, Ohio.

Mr. Setzler started his discussion with slides on photoelastic studies of the various types of welded joints, showing stress concentrations in incomplete and unbalanced welds under static and fatigue loading.

Examples of various weldments which had failed in service were shown, and in each case, an analysis of the cause of failure and the method of correction was pointed out.

Mr. Setzler presented the increase in the use of welded fabrications and the decline in the use of castings as a firm challenge to the welding industry to maintain the highest possible standards of design and shop practice.

Before the technical session, a sound color movie on the British steelmaking industry was shown. Also included in the movies were scenes taken at the last annual picnic by Robert Ryan.

A social hour, including the serving of cider and doughnuts, concluded the evening's program.

Detroit

The regular monthly meeting of the Detroit Section was held on Friday, Oct. 7, 1949, in the Auditorium of the Engineering Society of Detroit. Dinner preceded the technical meeting.

Speaker at the technical session was T. J. Crawford, Consulting Engineer, whose subject was "Design for Resistance Welding." Mr. Crawford drew from his experience extending back more than twenty years in graphically pointing out what can be done on the design board to improve the manufacture of industrial products. Using the Visu-Cast and a very excellent set of slides, Tom showed good and bad practice in selected illustrations, and how design was changed to simplify welding practice.

In this talk, Mr. Crawford, who is also Chairman of the Section, showed that he could present a down to earth talk on design for welding which proved extremely interesting and instructive, and one enjoyed by even those whose interests were not in the resistance welding field. His talk also showed comparative costs of various kinds of welding on a given job.

A sound color film "Copper Mining, Smelting and Refining" was shown through the courtesy of the Anaconda Copper and Mining Co.

Sixty-nine members and nine guests were present.

Eastern Illinois

This Section was officially organized on Oct. 14, 1949. The following officers were elected: *Chairman*—Dale Minyard, Electric Steel Foundry, Danville, Ill.; *First Vice-Chairman*—B. Singer, Illinois University, Champaign, Ill.; *Second Vice-Chairman*—Bill Alston, Alloys Castings Co., Champaign, Ill.; *Secretary*—H. F. Depke, Depke Service, Danville, Ill.; *Treasurer*—Fred Cowles, Danville, Ill.; *Members-at-Large:* 3 years—Paul Smoot, Danville, Ill.; 2 years—Art Hughes, Hoopeston, Ill.; 1 year—Paul Cummins, Danville, Ill.

Meeting night has been selected as the fourth Wednesday of the month and meetings will be held at the Plaza Hotel, at 6:30 P.M.

Hartford

Regular monthly meeting of the Hartford Section was held on October 13th at the Rockledge Country Club, West Hartford, Conn.

A. B. Tesmen of the North American Philips Co., gave an illustrated talk on "Contact Electrodes and Application," which presented new facts, methods and developments.

Kansas City

A well-attended and interesting meeting was held on October 14th. L. E. Kunkler, President of the Metallizing Company of America, Chicago, gave a clear-cut talk on Metallizing, Its Technique and Purpose. An actual demonstration on preparing the work and the Metallizing procedure was made by Mr. Kunkler and an assistant.

Ninety-two members and guests were present.

This program was sponsored in conjunction with and through the courtesy of the Libby Welding Co., who also made arrangements for refreshments to be served.

Lehigh Valley

A. B. Tesmen, Development Engineer, North American Philips Co., Inc., Dobbs Ferry, N. Y., was the guest speaker at the monthly meeting of the Lehigh Valley Section which was held in Fritz Engineering Laboratory, Lehigh University, Bethlehem, Pa., on Monday, November 7th. Q. E. Charlesworth, Section Chairman, presided at the meeting.

Mr. Tesmen gave an illustrated talk and directed a demonstration of contact welding electrodes. He told of the new design and special type of coating in the contact welding electrodes which offers many advantages.

The 75 members and guests witnessing the demonstration were greatly impressed with the ease of operation of contact electrodes.

A dinner was held prior to the technical session.

Los Angeles

Thursday evening, October 20th, the Los Angeles Section held its regular monthly dinner meeting.

Vice-Chairman C. T. Sweitzer, introduced the coffee speaker, who was C. A. "Charlie" Babbitt, Vice-President, Cal-Metal Corp., Torrance, Calif. Charlie told of his observations made on a recent trip to the Israel Nation. His comments on their economic and industrial progress and objective planning were extremely enlightening.

Principal speaker was A. P. Maradudin, Materials Engineer, Standard Oil Company of California, El Segundo, Calif. "Alex" spoke on the subject "Refinery Welding." So as to acquaint the audience with refinery corrosion and temperature conditions, a simplified process flow chart was shown and explained. This chart illustrated the flow of crude oil from subterranean origin at the well to the principal groups of finished petroleum products emerging from a refinery. The subject was divided into major items of utility piping process piping, pressure vessels and pumps.

Of the first group, only one service was described as requiring special attention, it was "steam piping."

Subsequent extensive discussion indicated the audience reaction to the speaker's expert handling of an important subject.

Louisville

Paul W. O'Malley, Metallurgical Engineer, The McKay Co., York, Pa., was the guest speaker at the October 25th meeting held at Preston R. Kunz Restaurant. His talk on "The Arc Welding of Stainless Steel" was illustrated with lantern slides and followed closely an outline distributed to the audience.

Mr. O'Malley stated that the design and production of satisfactory stainless welds by arc welding involves three functions as follows: the actual welding and associated metallurgy; the strength and ductility requirements of the stainless weld; the corrosion resistance requirements of the stainless weld.

After a short discussion, a movie "Arc Welding of Stainless Steel" was shown, and the program closed with the serving of a Dutch Lunch.

Maryland

The second meeting of the season of the Maryland Section was held on October 7th at the Engineers Club in Baltimore.

W. F. Jahn, of the Federal Bureau of Investigation, was the coffee speaker. His subject was "The Work of the F.B.I."

Technical speaker was John B. Tinnon, Vice-President of the Metal and Thermit Corp., whose subject was, "Management, Welding Is Your Business." Mr. Tinnon gave a synopsis of managerial relations to technical aspects of welding.

Michiana

The Michiana Section continued its current season by successful tapping its local talent again. A subject not often encountered in the average Section's program—"Problems of a Welding Job Shop"—was very nicely discussed by Erwin Laylin, owner-operator of Laylin's Welding Shop, Dowagiac, Mich. Mr. Laylin pointed out the wide diversity of materials that come in to such a shop, and discussed some of the methods that are used in this weldery to successfully accomplish the task. One job discussed was of particular interest. It was the repair of a large church bell that had been cracked during a fire. This proved beyond a doubt that even the job shop operator must know what material he is welding and must follow satisfactory metallurgical procedures.

Also brought to light as problems of a job shop were public relations, keeping books, government reports, etc., all of which are operations that seldom plague the welding expert in industry.

Milwaukee

In the absence of the Chairman, the October meeting held on the 28th at the Ambassador Hotel, was conducted by the Vice-Chairman. The technical speaker was C. M. Sheridan, Associate Director of Research, Allegheny Ludlum Steel Corp., Research Laboratory, Brackenridge, Pa. Mr. Sheridan described the various grades of stainless steels available and explained the effect of heat on them especially with respect to mechanical properties and corrosion resistance.

An interesting coffee talk on the desirability of making a will was presented by a local speaker.

New York

"New Developments in Resistance Welding" was the title of the paper presented by J. F. Deffenbaugh, Chief Electrical Engineer, of the Federal Machine and Welder Co., Warren, Ohio to the members of the New York Section on October 11th.

Mr. Deffenbaugh described the advantages to be derived from the application of slope control in resistance welding. He brought out the fact that electrode life is greatly increased by use of slope control when spot welding aluminum alloys, and that electrode pickup is reduced considerably resulting in less frequent tip cleaning. Mr. Deffenbaugh also discussed the characteristics of frequency changer welders stressing the electrical advantages that may be realized from their use in reducing kva. demand and improving power factor Metallic rectifier welders were also treated in his discussion.

Russell W. Staggs, Sales Manager, Electronic Controls, Westinghouse Electric Corp., Buffalo, N. Y., ably served as Technical Chairman of the meeting.

Following dinner held in Schwartz's Restaurant, members attending also heard an interesting after-dinner talk by Mathias R. Griffin, Special Agent, Federal Bureau of Investigation, describing some of the activities of the Bureau in counteracting espionage during the war.

The meeting arrangements were handled by G. L. Baker, 1st Vice-Chairman of the Section.

Northwest

The October 10th meeting was called to order by Chairman Toll in the Lodge Room of the Covered Wagon, Minneapolis. A committee report on membership was given by Co-chairman Schwabe. The Section was told of the newly organized membership contest whereby the Section was divided into two teams, one headed by Mr. Schwabe and the other by Co-chairman Ford. The team securing the most new members would be amply rewarded at the expense of the loser.

The Section was addressed by Prof. T. L. Joseph of the University of Minnesota on "A Look at the Iron Ore Situation." Professor Joseph is a recognized authority on iron ore, metallurgical coke, blast furnaces and special adaptions of the open hearth and electric furnace in the treatment of Minnesota manganiferous iron ores. He reviewed the reserve deposits of ore in Minnesota and in various sections of the world, touching on the future of the iron industry and its relationship to the future of Minnesota.

The talk was followed by a Technicolor movie "Steel-Man's Servant."

Northwestern Pennsylvania

The October meeting of the Northwestern Pennsylvania Section was held on the 25th in the G. E. Community Center, Erie, Pa. Technical speaker was R. T. Braymeier, who spoke on "Inert-Gas Arc Welding." A film, "Battle for Survival," was also shown.

Oklahoma City

Regular monthly meeting was held on October 25th in the Huckins Hotel. Technical speaker was Howard N. Simms, who spoke on the Application and Control of Welding Processes. Mr. Simms used slides most effectively in his lecture. His manner and method of presentation were excellent.

Philadelphia

The October meeting of the Philadelphia Section held on the 17th continued the same fine enthusiasm and interest that started the fall season, despite interference with the Annual Meeting in Cleveland and the absence of many regulars.

Paul F. Croley, Chief Land Planning Division, Philadelphia Planning Commission, was a most interesting coffee speaker. His talk and slides on the proposed "Philadelphia Expressway" were very heartening to those who must encounter the present congested traffic conditions around Philadelphia.

The business of the evening was in the capable hands of Everett Chapman, Consulting Engineer. His talk on "Welded Joints" which he illustrated with slides and a film showing the results of stress studies on photoelastic models was extremely useful.

Rochester

The Rochester Section opened its fall monthly meetings October 21st with a plant visit at the Rochester Products Division of General Motors. Walter Kazoroski, the new chairman, introduced R.

B. Knight, Works Manager of Rochester Products, who welcomed the record turnout of members and friends. A chicken dinner, second to none, was served in the plant cafeteria with the compliments of the company.

The tour of the plant was conducted by some of the company's most able department heads, who did an excellent job of explaining in detail the points of interest, and who answered all questions. The welded tubing process proved to be one of the high points of interest. After the tour, Rae I. Hahn, superintendent of tube manufacturing, enlarged upon the subject of tube welding by the use of visual aids, and conducted a question-and-answer period on that subject.

San Francisco

Postwar trend has been toward designing on yield strength rather than on tensile strength, W. A. Saylor, Chief Metallurgist for Consolidated Western Steel Co., told members of the San Francisco Section at their meeting on October 24th held at the Engineers Club.

Reviewing developments in welding processes since the end of World War II, Mr. Saylor said hydrogen has proved to be the main contributing feature toward underbaked cracking. He stressed that designers should insist on proper preheating and postheating when necessary, inasmuch as most problems in welding come right back to the carbon content of the material. He warned, however, that "preheat" is just an aid—not a cure-all.

A sound film produced and directed by R. Hereford, Assistant to the vice-president of Consolidated Steel, was featured, showing the history of water development in California.

Susquehanna Valley

The newly formed Susquehanna Valley Section held its first meeting in the ballroom of the Hotel Berwick, Berwick, Pa., on Wednesday evening, October 26th. The Section was officially organized on October 14th.

Following the dinner which was attended by forty-five welders, welding shop owners, welding engineers and others, the meeting was conducted by Olin H. Philips, Chief Metallurgical Engineer of ACF, who is the Chairman of the Section in its first year.

Movies preceded the speaker, E. C. Brekelbaum, Chief Engineer of the Harnischfeger Corp., Milwaukee, who spoke on the subject "Coordination of Engineering and Production in the Fabrication of Welded Products."

The speaker stressed the need for mutual understanding and willingness to work out welding problems between the engineer who designs, specifies and suggests procedure and the production department which makes the salable product.

A lively discussion followed the formal talk.

The following officers have been elected to serve the Section: *Chairman*—Olin H. Philips; *Vice-Chairman*—Stanley E. Bunn; *Secretary*—Charles E. Reedy; *Treasurer*—Robert Bellas; *Directors:* 3 years—W. E. Harding, L. A. Davis; 2 years—H. D. Swepston, W. P. Hindman; 1 year—J. F. Brandt, Fay E. Hopkins.

Toledo

The September 14th meeting was held in the nature of a plant tour through the Acme Power Plant of the Toledo Edison Co., which was most interesting to the group of twenty-seven who attended.

The October 12th meeting held in the Toledo Room of the Commodore Perry Hotel, was addressed by C. G. Herbruck, Assistant to Secretary, Lincoln Electric Co., Cleveland, who spoke on "Reducing Production Arc-Welding Costs." The speaker and subject were well received.

Tri-State

The October dinner meeting of the Tri-State Section was held on the 27th at Beckelman's Evansville, Ind. C. C. Keyser of the Bethlehem Steel Co. gave an illustrated talk on "Maintenance Welding," which was very well received.

Western Massachusetts

On Tuesday, October 11, at Blake's Restaurant in Springfield, Roger Tuthill, Chairman of the Section, presented an excellent talk on "Basic Electricity as Applied to Welding." This talk, which was accompanied by a demonstration of the workings of a transformer, held the interest of the entire audience, regardless of previous knowledge of electricity.

Mr. Tuthill, who is an electrical engineer with the General Electric Co., commenced his talk by point out the analogy between water flowing in a pipe and current flowing in a wire.

The fundamental differences between a. c. and d. c. were then pointed out, followed by a discussion of the principles by which the two different types of power are produced.

Mr. Tuthill then demonstrated the operation of a small a.-c. transformer, with a variable core gap. The core serves to bend the lines of magnetic flux, produced by current flowing in the primary coil, around through the secondary coil, thus inducing current flow here.

The talk wound up with a discussion of rectifiers and capacitors, and was followed by a question-and-answer period.

On Tuesday, November 8th, at the Gilbert Barker Co.'s plant in West Springfield, Mass., the Western Massachusetts Section saw and heard an interesting demonstration of the welding of zinc base die castings by V. A. Henry, Welding Engineer with the Bendix Aviation Corp., South Bend, Ind.

Mr. Henry first demonstrated how to make welding rod for zinc base die castings.

The next demonstration illustrated the butt welding of two white metal plates about $^{3}/_{16}$ in. thick.

Some badly mangled die castings were then repaired. The first step in repair operations involves heating the area to be welded, and when the metal has softened sufficiently, dirt is scraped from the surface by means of a stainless-steel scraper, with a blade about $^{1}/_{8}$ in. wide.

Summarizing his demonstration, Mr. Henry stated that the greatest difficulty experienced by beginners can be traced to the use of too much heat and too little patience.

An informal question-and-answer period followed.

Western Michigan

The Western Michigan Section held its second meeting of the new season on Monday evening, October 24th, in Battle Creek, Mich.

The dinner meeting was held at Post Cereals Club House.

Following the dinner, W. R. Plummer, General Sales Manager, Progressive Welder, Detroit, spoke on "Design for Resistance Welding." Mr. Plummer delivered a very interesting talk illustrated with slides, by which he was able to mark on the slide the points he wanted to bring out. At the end of his talk, Mr. Plummer held a question-and-answer period. Some very interesting questions were answered in a manner very satisfactory to everyone.

The United Steel and Wire had planned a plant visit for the group following Mr. Plummer's lecture. The trip proved to be a very interesting one, as the major portion of their welding is of this type.

Wichita

A buffet supper was served at Watkins, Inc., Wichita, in advance of the technical session and plant visit on October 10th.

Speaker was L. E. Kunkler, President of Metallizing Company of America, whose subject "Metallizing, Its Technique and Purpose" covered the latest type of equipment and a 16-mm. silent movie showed many applications.

Following a plant visit of Watkins, Inc., a live demonstration of metallizing on shaft build-up was enjoyed by all.

This was a very fine meeting with an attendance of 80; the presentation was good, and the interest keen.

Worcester

The October meeting was held on the 26th at the Tower House, Worcester, Mass.

Following a social hour, a predinner movie, "March of Time's T Men," was shown.

Speaker of the evening was Lyell Wilson, Research Director, American Bureau of Shipping, New York. His subject was "Control and Inspection of Quality Welds." Mr. Wilson's philosophical approach to inspection problems, based on his thirty-three years' experience in inspecting and testing material for marine use, provided an interesting and instructive evening to the 60 members and guests who attended the session. He emphasized that the inspector's job was not solely to reject but, in a broad sense, by representing the buyer, user or builder of a product, he is actually an adviser whose main function is to interpret specifications for the producer and insure a product suitable for the purpose intended by the buyer.

At the conclusion of Mr. Wilson's talk, the importance of quality control was dramatically emphasized by slides depicting the failure of the ship, *Schenectady.*

WELDING RESEARCH COUNCIL

of the Engineering Foundation

Sponsored by the American Welding Society and American Institute of Electrical Engineers
American Institute of Mining and Metallurgical Engineers, American Society of Civil Engineers
American Society of Mechanical Engineers, and Society of Naval Architects and Marine Engineers

Supplement to The Welding Journal, December, 1949

Effect of Buckles on Strength in Welded Ships

Under certain conditions of restraint, buckles in plate section reduce the strength of plate sections and may act as a notch. Under other conditions where equalization of stress under load is possible they may be harmless

by P. H. Take

FOREWORD

IT IS obvious that buckling is an indication of compressive stresses where such unfairness was not present in the member prior to fabrication. Such compressive stresses likewise indicate equal and opposite tension stresses in adjacent members for equilibrium. It is the purpose of this research to direct attention to a possible source of weakness in welded vessels.

Consider two parallel bars incapable of bending, separated and arranged as in Fig. 1. Any movement

P. H. Take is Welding Engineer, Halifax Shipyards Ltd., Halifax, N. S.

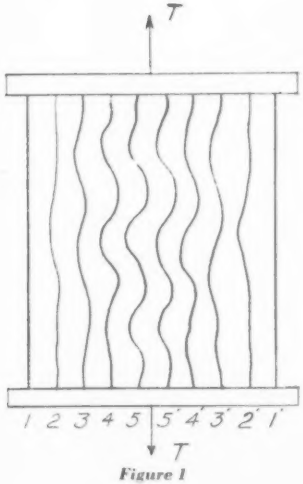


Figure 1

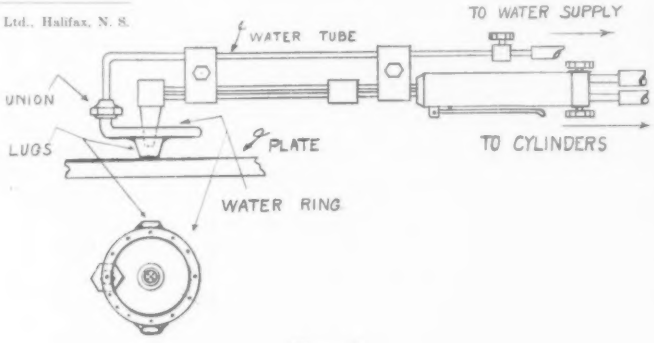


Figure 2

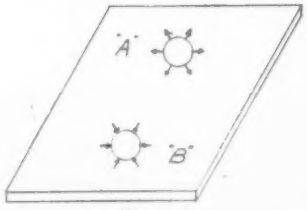


Figure 3

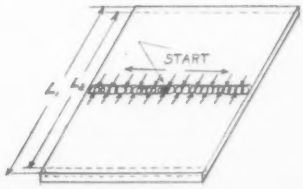


Figure 4

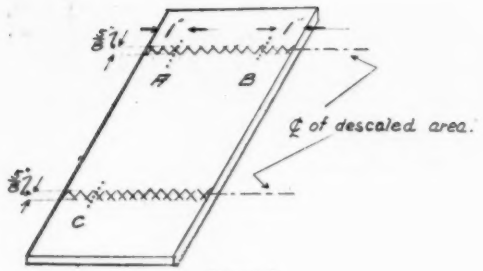


Figure 5

of bars must conform to the stipulation that they remain parallel.

Ten strings in pairs of equal length: 1,1′; 2,2′; 3,3′; 4,4′; and 5,5′ are strung between the bars in descending order of lengths such that 5,5′ are equal in length to each other but longer than 4,4′; 4,4′ being of same length, but each longer than 3,3′, etc. Thus

$$5 = 5' > 4 = 4' > 3 = 3' > 2 = 2' > 1 = 1'$$

Suppose ultimate strength of each string is exactly 1 lb., then maximum value of T would be $2 \times 1 = 2$ lb. Were strings of equal length, T would equal 10×1 or 10 lb.

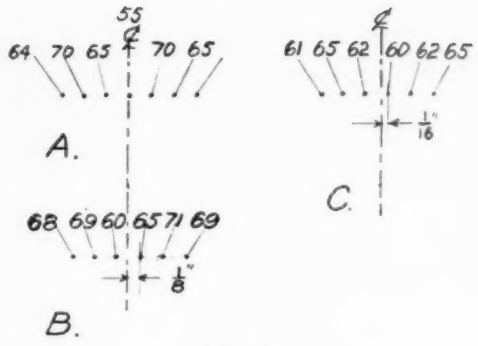


Figure 6

Suppose now that two springs taking a compressive load of $^1/_2$ lb. each are substituted for 5,5′; we now have a condition such that T cannot exceed 2 lb. $- 2 \times {}^1/_2$ lb. = 1 lb.

It would appear that this is the similitude of the factors to be considered in the case of suddenly applied loads on deck structure when deck plates do not lie fair. The strings with little elasticity present an analogous condition to that of steel under suddenly applied loading when little elongation is observed.

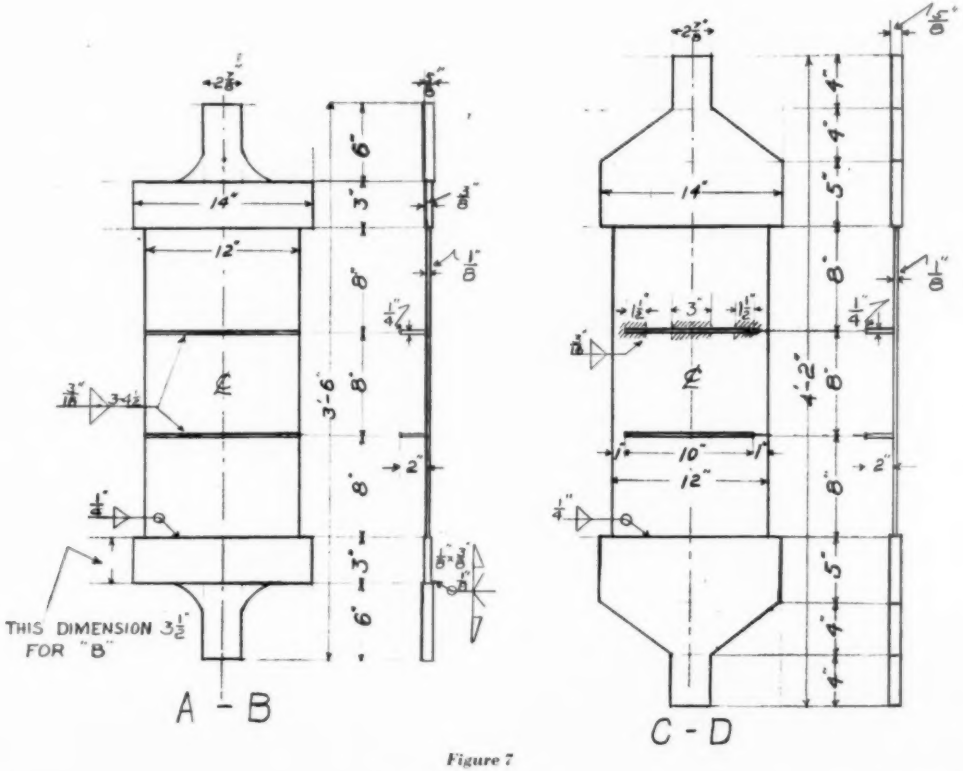


Figure 7

To reduce this reasoning to practicality for trial by experiment presented a problem. However, the difficulty of causing transverse rolls or dishing in the center of a plate without adding appreciably to the net section or changing the physical properties of the sides of the plate was finally overcome.

This was accomplished by shrinking the sides of the plate with the device illustrated in Fig. 2. This device consists of a standard cutting torch fitted with a water tube, control valve and a circle of pipe surrounding burner tip with holes on underside to provide water curtain.

In use, only the preheater orifices are used. This device is drawn across the plate in such a way that red heat spot just lags the burner tip slightly. The water keeps the plate surrounding the heated area cool. Heating of plate is not carried to extreme of roughing the surface. Distance lugs compel proper working distance of flame from plate.

Consider (Fig. 3) a plate with spot *A* brought to red heat. Heat causes local area to expand, generating compressive stresses outward. The surrounding cool plate acts as a vise preventing appreciable expansion laterally. Spot must then upset. During cooling, this upset portion contracts causing a tension stress as at *B*. Application of water "around" spot merely ensures localizing of heat.

If we progress across entire width of plate, starting at the center and working out with an infinite number of spots, we now have condition as in Fig. 4.

If L be original length of plate, $L_1 - L_2$ will be found to be $^3/_{64}$ in. per pass under normal conditions ($^1/_8$-in. plate) of no restraint and this contraction is quite precise.

To determine variation of hardness, if any, due to flame and water action, a piece of plate $4^1/_2$ x 12 x $^1/_4$ in. was torch treated with two passes (Fig. 5).

Width of descaling due to torch was approximately $^5/_8$ in. Six Rockwell *B* measurements were taken at each of three different locations. At *A* one Rockwell was taken on center line of descaled area; at *B* center Rockwell was displaced $^1/_{16}$ in. from center line of torch path, and at *C* center Rockwell was displaced $^1/_8$ in. from center line of descaled area, thus giving good exploration. Results in Rockwell *B* were as given in Fig. 6. No hardening effect is indicated.

Tensile tests on two similar plates, one of which was shortened in test area $^3/_{16}$ in. by four passes of torch, showed no appreciable difference. When elongation value of treated plate was corrected as to gage length due to shortening, no appreciable difference in ductility was observed.

These results led to a closer observation of the effect of the torch during actual operation. It was apparent that rate of heat input was considerably greater than cooling rate. The temperature gradient on the leading side of the torch was essentially that of the difference between flame temperature and that of plate temperature, less preheating effect of conduction. The temperature of the plate, however, 6 in. from trailing edge of torch, was such as to be uncomfortable to the touch. In other words, the process could not be described as of a violent quenching action.

The speed of the torch is about 12 in. per $2^1/_2$ min.

The purpose of the water is to keep the surrounding metal cool until after the passage of the hot spot.

It was concluded that on steel of this carbon content (C = 0.16/0.24) no change of physical properties need be expected by the use of this process. This method therefore was used to cause dishing effect in simulated deck sections as outlined in Fig. 7.

It will be observed that *A* and *B* (Figs. 9 and 10) are similar except in *A*, $^3/_8$-in. attachment plate is 3 x 14 in., whereas in *B* it is $3^1/_2$ x 14. The stiffeners on *A* and *B* were deliberately run out to edges of plate although not considered a good welding design for this type of loading.

C and *D* (Figs. 11 and 12) were fabricated using $^5/_8$-in. attachment plates, 5 x 14 in. to and at shoulders. Stiffeners were not extended to edge of plate as in *A* and *B* but were terminated 1 in. from each edge which allows for equalizing of stress due to plastic flow thus alleviating notch effect and allowing for better welding.

It was intended that *C* and *D* be actual test pieces for this research, *C* being control and *D* test piece. Actually *A* and *B* were afterthoughts.

Specimens *A* and *D* were edge shortened by four passes of torch on each side of plate $3^1/_2$ in. long per-

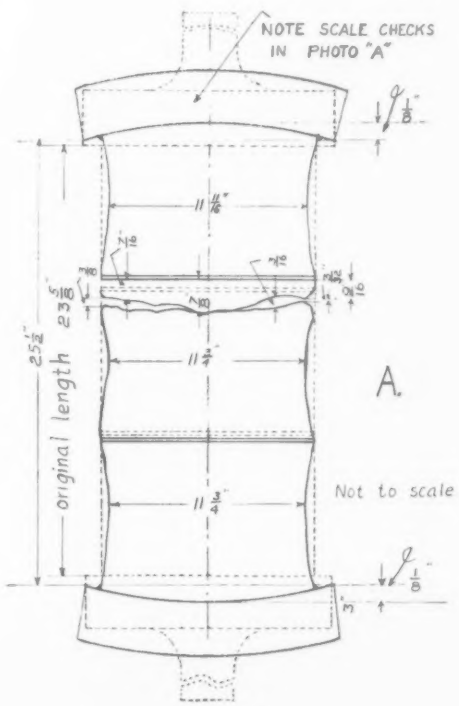


Figure 8

pendicular to edge of plate, between stiffeners and between stiffeners and attachment plates.

Direction of torch path was outboard.

It should be noted that after a certain degree of dishing effect was achieved, further torch treatment upset plate by approximately 0.002 in. in way of torch path, but with no appreciable increase in dishing effect. Tendency for plate to attenuate along edge away from torch path after this stage was reached, led to the assumption that stress values somewhat approaching the yield point of steel had been reached along the edges of the plate. This would give some idea of the stress necessary to produce buckling or dish effect in center.

Incidental to foregoing paragraph, separate experiments with plate $^1/_8$ x 80 x 20 in. rigidly constrained at ends in steel frame showed conclusively that plate upset in way of torch path putting the plate under increasing tension up to a certain point. Further treatment with water torch did not appear to increase tension, but upsetting of torch path was accompanied by attenuation of plate on either side of torch path. Measurements were made by micrometer.

It thus appears that within the range investigated there is a certain tension value short of yield point beyond which torch will not cause increased tension in the plate as a whole. Due to attenuation, however, it is a safe assumption that local unit stress values in attenuated area were increased.

Topography of specimens *A* and *D* after edge shortening was recorded but is not reproduced in this article. Specimens *A* and *B* were placed in a tensile machine with sufficient tension to straighten edges. Maximum dishing effect was observed to be but $^3/_{16}$ in.

It should be noted that torch path to secure this dishing effect was $3^1/_2$ in. on each side or 7 in. of the total 12 in. width of plate (see figs. 9 and 12). The attempt was made to secure a greater dish effect by using a torch path of only 2 in. per side or 4 in. of the total 12-in. width of plate (see Fig. 9). This was found to have no effect whatsoever. Apparently the strongback tendency of remaining 10 in. of plate coupled with the nearness to the edge of plate of starting point of the torch prevented shrinkage.

Results of tensile tests on these sections were as given pictorially in figs. 9–12, dimensioned sketches Figs. 8 and 13–15 and in the following table:

Specimen	*Yield, lb.*	*Ultimate, lb.*	*Speed of loading, in./min.*	*Remarks*
A (Fig. 9)	68/76,000	84,400	Approximately 1	Tensile failure
B (Fig. 10)	62,000	80,000	Approximately 1	Initial failure at undercut in weld at end of stiffener
C (Fig. 11)	62,550	81,150	Approximately 1	Tensile failure
D (Fig. 12)	65,000	68,500	Approximately 1	Tensile failure

Figure 9

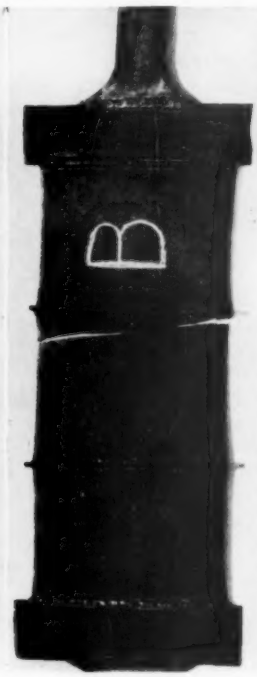


Figure 10

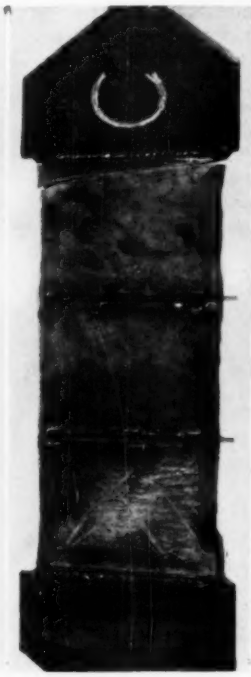


Figure 11

Figure 12

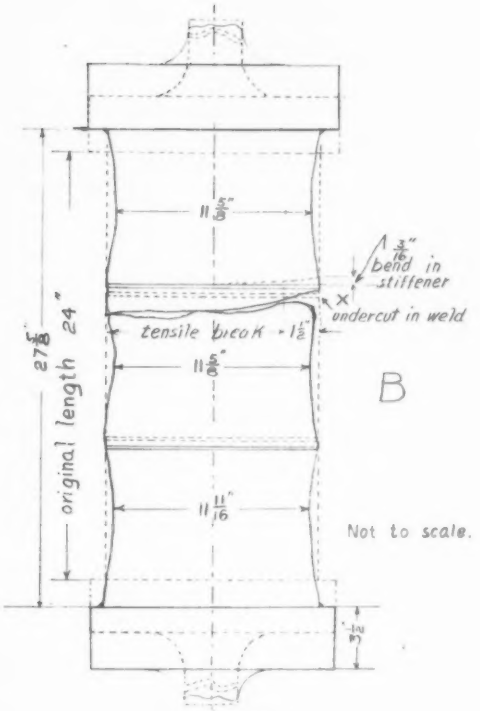
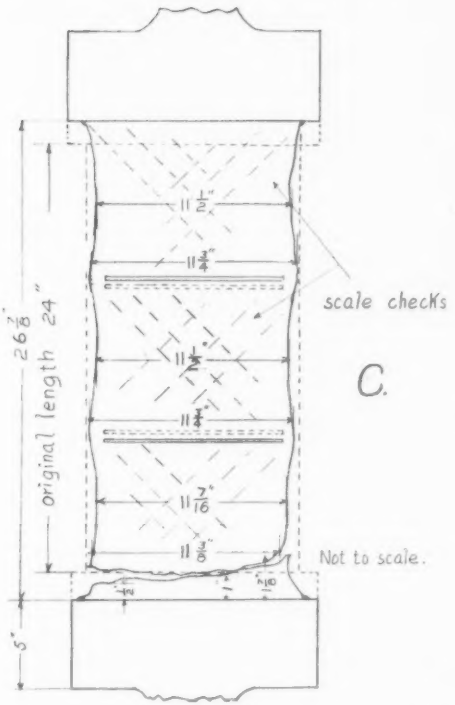


Figure 13



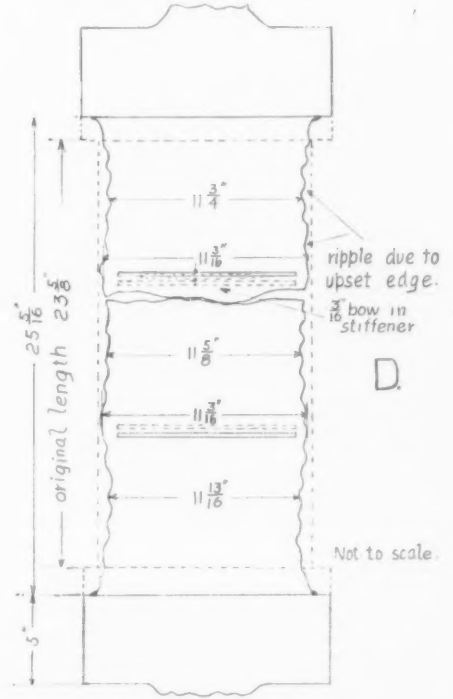
In *A* (Fig. 9) scale checks and deformation in attachment plates plainly visible in photographs indicate direction and nature of stresses. In this case attachment plates acted as equalizers distributing the load. It is to be noted that *A*, even with dish in plate and fully extended stiffeners, gave best results due to this equalizer action of end plates.

With *B* (Fig. 10) a slight overlap in weld concealed an undercut but even with this weakness and with fully extended stiffeners this weldment gave nearly as good results as *C* in which there is no suspicion of faulty weld and stiffeners were shorter allowing for plastic flow at edges of plate. These results it would appear are also due to the fact that end attachment plates deformed slightly, in other words, they acted as equalizers.

C and *D* (Figs. 11 and 12) give comparative results showing weakening effect of buckling in the presence of rigid end restraint, i.e., where end attachment did not permit equalization of stresses.

As already intimated, only $^3/_{16}$ in. maximum dishing was obtained across 5 in. of plate. Seven inches of the 12-in. plate was used to cause and hold dish.

A larger capacity tensile machine would enable wider sections to be used which would probably increase the dish and at the same time lower the tension/compression plate width ratio. Under such conditions it could be



(Top) Figure 14 (Bottom) Figure 15

expected that tensile values as between a straight section and a distorted section would show a much greater variation in effective strength. Unfortunately, also, it was not possible to subject these test specimens to other than a slow loading condition in which, as seen in photographs and sketches, considerable elongation took place.

It would have been most desirable to have performed these tests under conditions of suddenly applied loading under which it is a safe assumption the results would have been most startling.

The test figures and descriptive results appear to show conclusively that with this type of loading that:

(i) Under conditions of severe parallel end restraint the presence of buckles in plate sections seriously affects the strength of those plate sections. In other words, if a buckled plate section is welded to a much heavier end section incapable of plastic flow under stresses imposed by the buckled section, then tension failure can result at a much lower value than the cross section of the plate would indicate.

(ii) It follows from (i) that unequal stress conditions imposed by buckling may introduce an effective notch not indicated by design.

(iii) It would appear that under conditions of slow loading slight buckles, slight weld defects, secondary welding design errors are relatively unimportant if the section under consideration receives its tension stress from another member capable of equalizing or conforming to the unequal stresses so set up.

(iv) The full tension value of a weldment composed of deck section, hatch connections and sheer strake forming the upper chord of a vessel is diminished by the compressive stresses necessary to produce the buckling in the deck section.

This means that it is probable in some cases that full tension load of upper chord is not only carried by hatch connections and extreme fibers of sheer strake remote from neutral axis but buckling may mean an actual increase in dead load as carried by sheer strake and hatch connections.

Acknowledgment is made to Dr. Allan E. Cameron and the Nova Scotia Technical College for the use of tensile machine.

RESISTANCE WELDING RESEARCH

The Resistance Welding Research Committee of the WELDING RESEARCH COUNCIL has formulated a $60,000 a year research program. It is seeking cooperation and funds from interested Industry. Half of the needed funds are already in sight or pledged. Progress Reports will be furnished to Contributors.

The research program includes the following:

Spot Welding of Structural Steel

A continuation of the study of spot welding low-carbon steel in gauges from 1/8" to and including 1/2". Effect of short-circuiting adjacent spot welds will be studied and methods for reducing these effects. Welding of dissimilar sheet thicknesses and multiple spot welding included.

Flash Welding

A study of temperatures needed for producing sound welds free from oxide, by correlating electrical characteristics during flashing and rate of burn-off with the temperature gradient produced back of the flashing faces.

Projection Welding

Proper shapes of projections to give best results, including resistance collapse will be studied. Proper welding schedules will be proposed for the most commonly used steels.

Fatigue of Spot Welds

A better understanding of fatigue and control of welding to improve the fatigue strength should result in a much wider application of spot welds.

Seam Welding

A vast amount of research has been carried out on spot welding, but little or no attempt has been made to determine optimum conditions for seam welding of mild steel, non-ferrous metals and stainless steels. Fundamental studies are required on size and spacing of spots, current interruptions, pressure, cooling and other variables involved.

Contact Resistance

All forms of resistance welding depend upon the presence of the electrical resistance that exists when metals are brought into contact. The fundamental laws of contact resistance are, therefore, of great importance to the welding industry. Increased knowledge of the laws of contact resistance and their application will make possible not only the improvement of present welding practice, but will also permit the welding of materials that cannot now be readily resistance welded.

For further information write to Mr. W. Spraragen, Director, Welding Research Council, 29 West 39th Street, New York 18, New York.

Analyzing Metal Transfer in Arc Welding

A new instrument has been developed for analyzing metal transfer in arc welding which provides an additional valuable tool for analyzing this complex phenomena. It is particularly well suited to studies of the influence of coating constituents on arc stability and metal transfer

by R. C. McMaster, D. C. Martin and A. Leatherman

METAL transfer is one of the most complex phenomena encountered in metal-arc welding. Many investigators have developed laboratory methods and instruments for the study of welding-arc metal transfer.[1-14] However, few of the laboratory instruments developed during these investigations were suitable for use under production welding conditions in industry.

The sensitive relay instrument described in this paper provides an additional tool for the study of metal transfer in welding arcs. The analyzer is a rugged and practical piece of equipment, involving no electron tubes or delicate components. It can be used in metal-transfer studies under production welding conditions, as well as in laboratory tests. It has been used successfully in studies of the influence of core wire on metal transfer. It appears to be particularly well suited to studies of the influence of coating constituents on welding arc stability and metal transfer.

RESULTS OF PAST RESEARCH

Previous studies have revealed many different mechanisms which contribute to metal transfer in welding arcs. These studies showed that, with most welding arcs, the major transfer of metal from the electrode to the work occurred during short circuits. The short-circuiting of the arc is a direct consequence of the metal transfer. Short circuits occur when the molten metal bridges the gap from the electrode to the work during its period of transfer. Compton and Van Voorhis[1] and Issendorff[2] in 1927 found that the heat produced at mercury cathodes was insufficient to vaporize more than a small fraction of the mercury lost. Schmick and Seeliger[3] obtained similar results with low-current iron arcs. As early as 1920, Eschholz[4] concluded that not more than 10% of the metal in the iron welding arc was transferred in the vapor state. The balance of the metal transfer apparently occurred as molten metal.

Compton,[5] Doan[6] and von Engel[7] found that a major portion of the heat produced at the arc cathode is used in melting the electrode. Alexander[8] found that the relative portions of the total arc energy dissipated at the anode and at the cathode of the welding arc varied with the constituents of the electrode coating. Suits[11-13] in his excellent studies of high-pressure arcs, found that the temperature and heat production within the column of the arc were greatly influenced by the heat-transfer characteristics of the environmental gases and by the effective ionization potential of the arc vapor.

Many efforts were made to photograph metal transfer in the welding arc. Early motion pictures, taken by Hudson,[16] Green[17] and Bung,[18] at speeds of fewer than 100 frames per second, were inadequate to reveal metal-transfer conditions accurately. Hilpert's later motion pictures at 2000 frames per second[19, 20] and synchronized oscillographic records indicated that the arc was short circuited at every transference of electrode material in down-hand welding. With bare rods the number of globules per second was a maximum at the optimum welding current found from experience. With coated rods, the number of short-circuits was considerably less than with a bare rod, yet the rate of melting was only 30% less. In overhead welding, the number and average duration of the short circuits were less in the case of heavily coated, electrode-positive rods than with electrode-negative bare rods.

X-ray studies by Doan and Weed[21] showed that, in overhead welding with coated rods, metal transfer occurred in the form of globules or drops projected upward from the electrode to the work without necessarily shorting the welding arc. Sack[22] made X-ray moving pictures of welding arcs. These showed that welding with a thinly coated rod and a short arc caused the molten metal on the electrode to make contact with the work. The metal transfer was carried out as a consequence of surface tension and pinch effects.

Doan[23] and Schmick and Seeliger[24] have moved welding electrodes rapidly across base plates, separating the deposited metal into individual globules. The metal was deposited as hollow and as solid globules, with diameters up to about two-thirds that of the welding

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electrode. However, Larson[25] collected very large numbers of very fine particles (0.001 in. diameter) when a thin metal strip was passed rapidly through a welding arc.

Larson[25] found that the globular metal transfer (which characterized overhead welding and welding with long arcs) was not greatly influenced by gravity, since the velocities of the globules traversing the arc gap often greatly exceeded those which could be accounted for by gravity alone. Doan[26–29] and Larson[30] suggested that vapor jets contributed significantly to metal transfer. With inert gases, however, Doan[27, 28] found that there was little evidence of vapor jet effects in propulsion of globules across the arc gap.

SHORT-CIRCUIT ANALYSIS

Many investigators have recognized the significance of welding-arc short-circuit analysis as a means for studying metal transfer. In down-hand welding with bare rods in air, Larson[25, 30] found that all the metal was transferred during the frequent short circuits. The frequency of transfer varied with arc length. About 20 short circuits per second occurred when the arc length was approximately equal to the rod diameter. Doan[21, 22] found that the duration of the short circuits correlated with the quantity of metal transferred. When he added 0.1% antimony to the bare rod, the frequency of short circuits rose to 50 per second. The rate of melting correspondingly increased 25 to 50%.

Hilpert[20] found that the number of short circuits due to metal transfer was a maximum at that welding current found optimum through welding experience. His tests showed that the average duration and number of short circuits with coated electrodes was much lower than with bare rods. He postulated that larger quantities of metal were transferred during each short circuit with the coated rod. The short circuits occupied about 3% of the arc time. Hilpert also observed transfer of drops of slag which did not short-circuit the arc. Needham[31] has recently prepared an excellent summary and analysis of these investigations.

Excellent high-speed motion-picture studies have been made of welding arcs at Rensselaer Polytechnic Institute, Johns Hopkins University and New York Naval Ship Yard. These 3000-frame-per-second color and infrared motion pictures show clearly the formation of the molten globules on the welding electrode. When globules attain sufficient size, they usually flow across the gap to the work, short-circuiting the arc. This flow of molten metal appears very much like liquid mercury pouring out of a soda straw. When most of the molten metal has been transferred, the bridging metallic filaments break down and explode violently, restriking the arc (Fig. 1).

The welding research laboratory at Rensselaer Polytechnic Institute has contributed several other excellent new instruments for the study of welding arc. Dr. Hess and his co-workers included among these a short-circuit

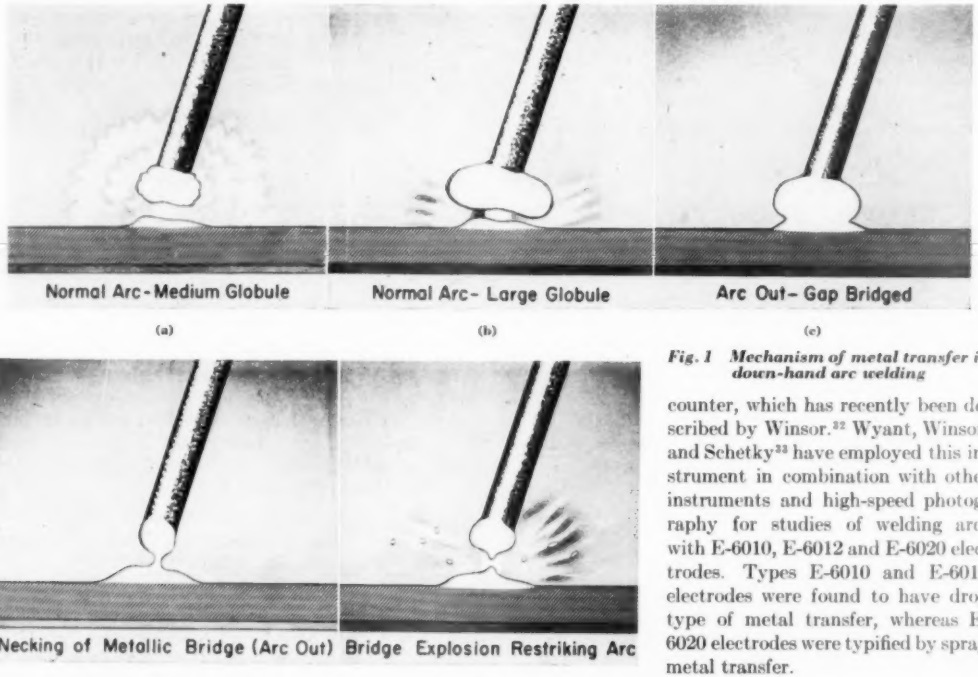

Fig. 1 Mechanism of metal transfer in down-hand arc welding

counter, which has recently been described by Winsor.[32] Wyant, Winsor, and Schetky[33] have employed this instrument in combination with other instruments and high-speed photography for studies of welding arcs with E-6010, E-6012 and E-6020 electrodes. Types E-6010 and E-6012 electrodes were found to have drop type of metal transfer, whereas E-6020 electrodes were typified by spray metal transfer.

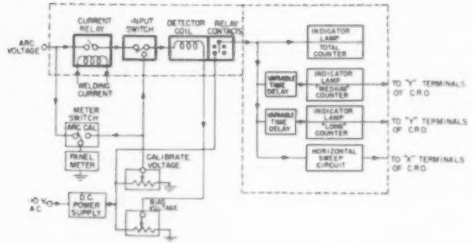

Fig. 2 Block Diagram of welding-arc short-circuit analyzer

The original R.P.I. short-circuit counter[22, 23] consisted primarily of electron tubes arranged as a parallel inverter. This actuated an electronic scaling circuit and a mechanical counter. The time constant of the R-C circuit determined the minimum detectable duration of short circuit as 1 millisec. This corresponds to the minimum duration of short circuit that can be reliably observed on magnetic oscillographs. The flip-flop thyratron circuit of this unit was later replaced with a fast-acting relay, similar to those employed in the Battelle short-circuit counter to be described later. In combination with eight electron tubes, this relay actuated a Cenco counter to count the total number of short circuits. The excellent results obtained with this short-circuit counter have been published.[22, 23] With E-6010 electrodes and a given voltage drop across the arc, the number of short circuits per second reached a maximum with d.-c. arc currents of 160 amp. With fixed welding current, the number of short circuits per second increased rapidly as arc voltage (and arc length) was decreased from 32 to 24 volts. These laboratory tests proved the validity and usefulness of the short-circuit counter as a means of studying metal transfer with various welding currents and voltages and with various electrodes.

THE B.M.I. SHORT-CIRCUIT ANALYZER

During the period of the Rennselaer development, a welding-arc short-circuit analyzer was designed and constructed at Battelle Memorial Institute, for use in studies of the influence of core wire on welding electrode characteristics.*

The B.M.I. analyzer differed from the Rensselaer unit in that it employed no electron tubes. It was constructed as a rugged portable instrument for use under production welding conditions. In addition to counting the total number of short circuits, it provided means for counting the number of short circuits falling in different duration intervals. Internal means were provided for determining and setting the relay operating voltages and measuring the time delays in the counter circuits. Because the unit consists only of electromechanical relays and fixed circuit components, it maintains calibration for periods of many months under rugged production service.

Functions of the B.M.I. Welding-Arc Short-Circuit Analyzer

The block diagram of Fig. 2 shows the relationship between the components of the short-circuit analyzer. A normally open series relay isolates the instrument from the welding circuit when the welding current is interrupted. This avoids any possibility of damage from the high open-circuit voltages. When the arc is struck and arc current flows, this relay closes, connecting the instrument across the welding arc. The normal arc voltage (usually 20 to 30 v.) closes the fast-acting mercury-contact detector relay. This relay, a Western-Electric type 276 G, operates in less than 3 millisec. Its rugged magnetizing coils can withstand up to three times rated voltage without damage. The contacts, which are wetted by mercury and operate in hydrogen, will interrupt currents up to 5 amp. Five poles are provided so that 2 circuits may be operated normally open and 2 may be operated normally closed (Fig. 3).

During short circuit of the welding arc caused by metal transfer, the voltage drop across the arc terminals is of the order of only 5 v. When such a short circuit occurs, the voltage across the coil of the detector relay decreases and the relay operates. It supplies a pulse of 100 v. d. c. to the three counter, indicator and auxiliary circuits, for the duration of the short circuit. Its operation also supplies a sweep voltage to a cathode-ray oscilloscope used in calibration of the duration of the short circuit. An internal biasing system is provided so that the detector relay may be operated at any

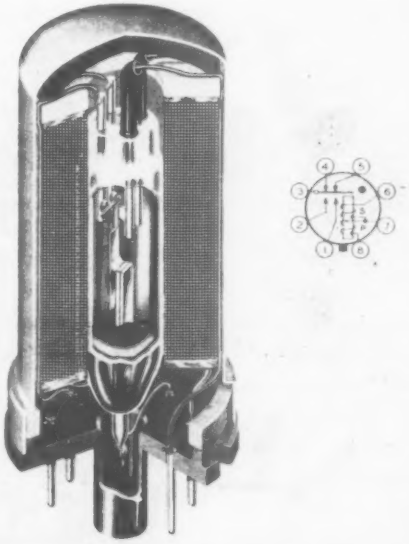

Fig. 3 Mercury contact relay W. E. type 276G

* The arc short-circuit analyzer was developed during the course of an investigation of the influence of core wire on welding electrode characteristics, sponsored by the American Iron and Steel Institute.

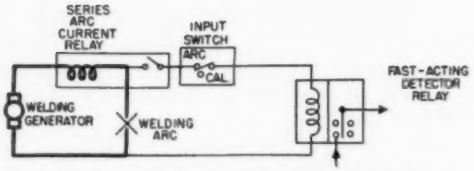

Fig. 4 Welding generator, arc and short-circuit detector

desired voltage level. A calibration circuit and panel meter make it possible to adjust and check the operation of the relay at any time. Figure 4 shows the simple circuit by means of which the detector relay is connected across the arc or across the calibration-voltage source.

Power Supply

Power for the analyzer is supplied from a 110-v., 60-cycle, single-phase source. An isolation transformer is necessary to prevent direct short circuits in the unit, if there are any grounds to the a.-c. line in the welding equipment. The alternating current is rectified by a 500-milliamp. selenium oxide rectifier unit and is filtered by a resistance-capacitance π network. The direct-current output voltage from the filter is 100 v. This circuit is shown in Fig. 5.

Counter Circuits

When the *detector relay* operates during a short circuit, it energizes three counter circuits (Fig. 6).

The *first counter circuit* consists only of a neon indicator lamp in parallel with a Cenco counter. The counter, paralleled by a 1-microfarad condenser and connected through a 500-ohm resistor to the 100-v. d.-c. source, operates in 1 millisec. It records a single count for each short circuit whose duration is one millisec. or greater.

The *second counter circuit* involves a time delay relay. This Stevens-Arnold millisec. relay is paralleled by a 20-microfarad capacitor and has an adjustable 10,000-ohm potentiometer in series with it. The potentiometer may be adjusted so that this relay will operate only after a short-circuit duration of from 3 to 60 millisec. In normal operation it is adjusted to count only short circuits of duration greater than 5 or 10 millisec. as desired.

The *third counter circuit* is identical to the second. Its time delay circuit may be adjusted for a longer time interval, for example, 10 or 20 millisec.

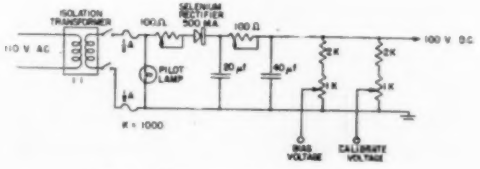

Fig. 5 Direct-current power supply

With these connections, the first or total short-circuit counter operates with each short circuit. The second counter circuit operates only when the welding arc is short circuited for a period of time longer than the minimum setting of its potentiometer. The third counter circuit operates only when the welding-arc short circuit is of still longer duration, as determined by its time delay adjustment. In order to obtain a rapid discharging of the time delay circuit at the end of each welding-arc short circuit, the time-delay capacitors are shorted through the detector relay when it returns to its normal position with arc voltage applied.

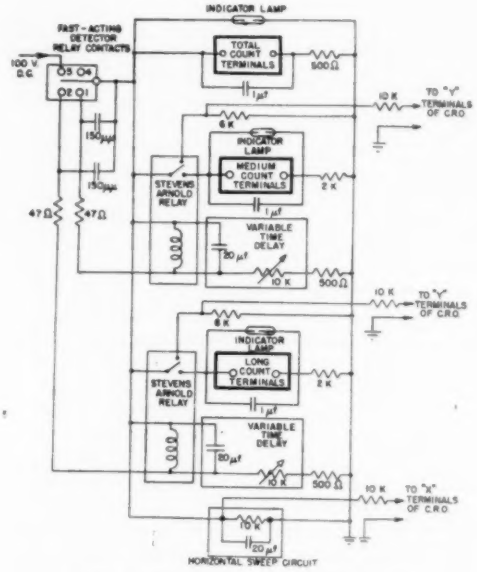

Fig. 6 Counter and time delay circuits

The detector relay also energizes an R-C circuit which provides a synchronized sweep voltage for a cathode-ray oscilloscope. Shown also in Fig. 6 are connections from each time delay circuit for the vertical terminals of a cathode-ray oscilloscope. When the oscilloscope is connected to these terminals, as indicated in Fig. 2, it may be used to calibrate and check the time delay circuits. Z-axis modulation at 1000 cycles per second provides 1-millisec. timing spots on the oscillograph trace. When the detector relay operates during a short circuit, a positive voltage is applied to the vertical oscilloscope terminals of both time delay relays. This voltage is removed only after the respective time delays permit operation of the relays, which pulse the external counters. The extent of time this positive voltage is applied to the respective Y oscilloscope terminals is an exact measure of the time delay between the operation of the detector relay and the initiation of the pulse to the external counter. Figure 7 shows typical oscillograms with the circuits adjusted for 3-, 6- and 20-millisec. time delays, respectively. In this way, the opera-

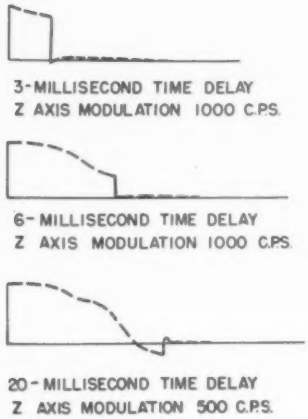
3-MILLISECOND TIME DELAY
Z AXIS MODULATION 1000 C.P.S.
6-MILLISECOND TIME DELAY
Z AXIS MODULATION 1000 C.P.S.
20-MILLISECOND TIME DELAY
Z AXIS MODULATION 500 C.P.S.

Fig. 7 Typical time delay circuit calibration patterns

tion of the time delay circuits and relays may be checked with no tools other than an audio oscillator and a cathode-ray oscilloscope. Over many months of operation, however, no deviations in time-delay calibrations have occurred in the instrument.

Each of the counter circuits actuates a neon lamp on the panel of the instrument, as well as a Cenco counter external to the instrument. Any other type of counter might be employed, if desired. The indicator lamp makes possible a quick visual evaluation of welding-arc conditions. It is possible to use the indicator lamps and the time-delay adjustment potentiometers to obtain a quick estimate of the average maximum and minimum durations of welding-arc short circuits. This is often helpful when it is desired to select the time-delay intervals which will provide a maximum of information.

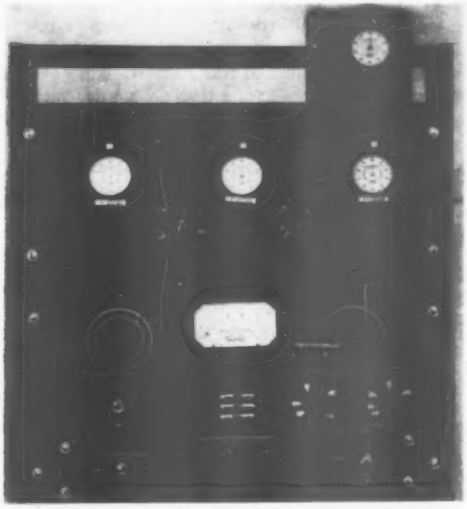

Fig. 8 The welding short-circuit analyzer

Function of Controls and Meter

The control panel (Fig. 8) of the welding-arc short-circuit analyzer supports a meter which is used for two purposes. In the "Calibrate" position, it is used as a voltmeter with 150-, 50- and 10-v. scales. It serves both to measure the average arc voltage during welding operations and to measure the calibration voltage applied to the detector relay (when it is being adjusted for a specific operating voltage condition). In the "Arc" position, the meter reads *the average percentage of operating time during which the arc is short circuited*. Three scale ranges are provided, 0–10, 0–50 and 0–100% outage time. With arc voltage applied and with no short circuits, the meter reads zero (Fig. 9). A large capacitor damps the needle movement, so that average arc voltages or short-circuit times may be read easily. The control panel, Fig. 8, provides a *bias voltage-adjustment potentiometer* and a *bias on-off switch*, which are used to set the operating voltage of the detector relay. The *calibrate voltage control* makes it possible to vary the calibration voltage applied to the detector relay during adjustments. With these controls, it is possible to determine and set the drop-in and drop-out limits of the detector relay to a fraction of a volt. To calibrate the detector relay, the calibration voltage is connected to the *input terminals* by means of the *calibrate switch*. The calibration voltage is then varied upward and downward until the detector relay operates, flashing the neon indicator lamp. The operating voltage is then read directly from the panel voltmeter. This is the

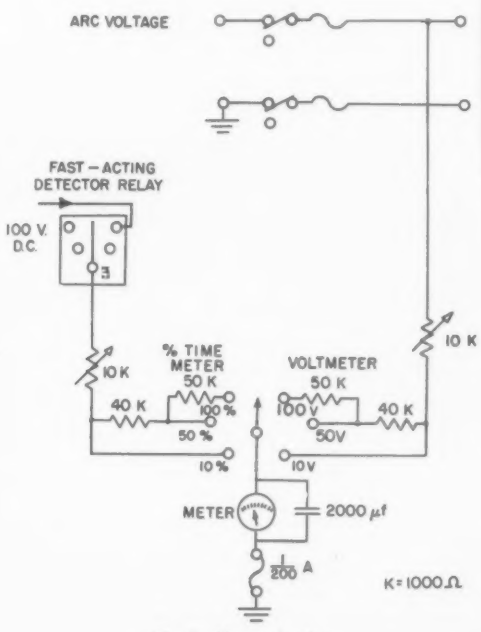

Fig. 9 Meter circuits

value to which the voltage across the arc must drop in order to actuate the counting circuits. This level may be varied continuously from 2 to 30 v.

The panel *time-delay controls* may be set for time delays ranging from 3 to 50 millisec., with an accuracy of about $^1/_2$ millisec.

External Counters

To record quantitative data, the square wave pulses from the short-circuit analyzer actuate external counters. Either mechanical or electronic counters may be used. The B.M.I. Analyzer employs four Cenco high-impedance mechanical counters. The Cenco counters will count 120 pulses a second. This corresponds to a pulse width of 8 millisec. The analyzer panel has a response speed measured oscillographically of approximately 1 millisec. Consequently, the counters as supplied by the manufacturer are so slow that they would limit the minimum duration of short circuit which they record and fail to record short outages. A 1-microfarad capacitor was placed across the counter terminals. The charge path for this capacitor is shorter than the discharge path and effectively lengthens the pulse. By increasing the voltage across the counter terminals, in addition to the capacitor across the terminals, the operating time was reduced to 1 millisec. Since a 2-millisec. pulse is necessary to actuate the Cenco counters, an actual pulse must last 2 millisec. longer than the actual time delay measured on the oscilloscope. This should be remembered in calibration of the two time-delay dials. By reducing the series resistance to only 500 ohms, a 1-millisec. response was obtained for the total outage counter.

PERFORMANCE TESTS

The welding-arc short-circuit analyzer was calibrated for voltage, per cent time short circuited and time delays immediately after construction. These calibrations have not changed measurably at the end of several months of continuous operation.

The performance of the unit, under production welding conditions, was checked by means of a Miller multi-element magnetic oscillograph. Simultaneous oscillograms were taken of the voltage across the arc, the voltage on the output side of the detector relay and the output of each of the time delay relays. A typical result taken directly from the oscillograms is shown in Fig. 10. The top curve shows the arc voltage as measured. The second curve shows the duration of the operation interval of the detector relay. It will be noted that the detector relay closed approximately 2 millisec. after the arc voltage dropped below the critical level for which the relay was adjusted. At the end of the short circuit, when the voltage across the arc again rose to its normal value, the relay opened 2 millisec. after the arc voltage passed through the operation level. As a consequence, the pulse delivered to the total short-circuit

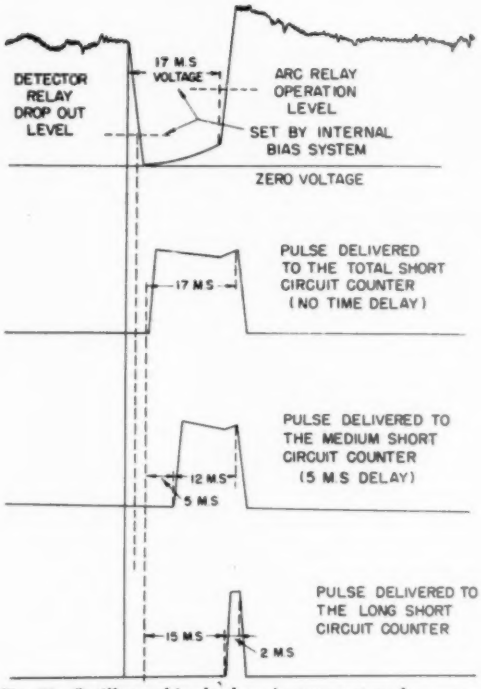
DETECTOR RELAY DROP OUT LEVEL
17 M.S VOLTAGE
ARC RELAY OPERATION LEVEL
SET BY INTERNAL BIAS SYSTEM
ZERO VOLTAGE
PULSE DELIVERED TO THE TOTAL SHORT CIRCUIT COUNTER (NO TIME DELAY)
17 M.S
PULSE DELIVERED TO THE MEDIUM SHORT CIRCUIT COUNTER (5 M.S DELAY)
12 M.S
5 M.S
PULSE DELIVERED TO THE LONG SHORT CIRCUIT COUNTER
15 M.S
2 M.S

Fig. 10 Oscillographic check on instrument performance during metal transfer, showing welding arc voltage, and operation of the detector and time delay relays

counter was the same in length as the duration of the actual arc outage voltage. The third curve shows the result of setting one of the time delay circuits for a 5-millisec. delay. The pulse delivered to its counter was 12 millisec. long and started 5 millisec. after the pulse delivered to the total short-circuit counter. The lowest curve shows the pulse delivered to a counter circuit set for a 15-millisec. time delay. Only 2 millisec. duration of pulse were applied to this counter. Had the time delay circuits been set for a time delay greater than 17 millisec., the counters supplied by those delay circuits would not have been actuated.

Oscillograms were taken of these quantities through several operating conditions and several different time-delay settings. In all cases the relays operated properly as designed, regardless of the duration of the arc short circuit in the range from 1 to 50 millisec. Figure 11 shows typical sections from a single oscillogram, including several different outages.

Several tests were carried out in which the counters were checked against the outages shown by the oscillograms. In all cases, the counters had recorded all outages with durations greater than the true limit for which they were adjusted. No operational failures were observed through several hundred short circuits measured in tests scattered over a period of several weeks.

At present, the unit has been in operation for a period of 1 yr. without significant change in calibration

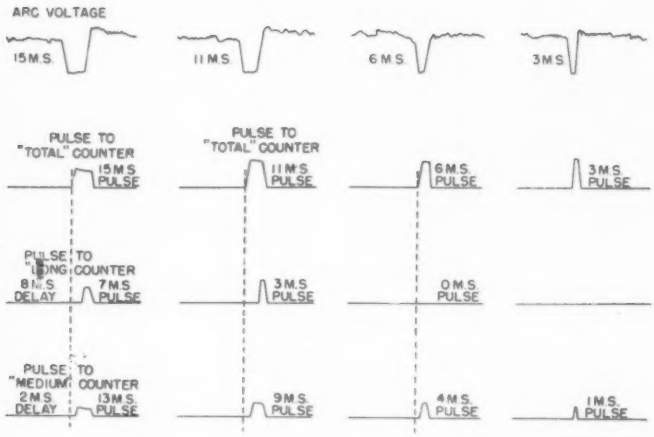

Fig. 11 Oscillographic check on instrument performance during metal transfer

and without an operational failure. It has shown itself to be a reliable and rugged instrument capable of taking the abuse common under production welding conditions, and of giving accurate and reliable data under all operating conditions.

TESTS OF WELDING ELECTRODES

The short-circuit analyzer was employed in welding tests with bare, E-6010 and E-6012 electrodes made with rimmed and capped core wires. Metal transfer from these electrodes to the work occurs by means of short circuits (when the molten globule on the electrode tip grows large enough to contact the molten pool on the workpiece and short out the arc). In the E-6020-type electrode, the molten metal passed across the arc gap from the electrode to the workpiece in the form of spray or in fine droplets, without shorting the arc. Consequently, no short circuits due to metal transfer could be measured with type E-6020 electrodes with the metal-transfer analyzer.

Influence of Arc Voltage and Current on Short-Circuit Characteristics of Electrodes

The arc voltage at which any given electrode operates is related to the length of the arc. It was assumed that the short-circuit frequency of an electrode is also influenced by arc length. Tests were made with various arc voltages and currents to determine if the current also influenced the short circuit characteristics.

Tests with various arc currents and voltages were made with one commercial brand of $^{3}/_{16}$-in. E-6012 welding electrodes. Ten electrodes were used to make these welds with an automatic head, for each combination of current and arc voltage. Ten welds were made at each of 18, 20, 22 and 24 arc volts. Currents of 140, 175 and 220 amp. were used at each arc voltage. Figure 12 presents the results on the basis of the total number of short circuits per second. In addition to the total number of short circuits, the number of short circuits 10 millisec. or longer was measured. The number

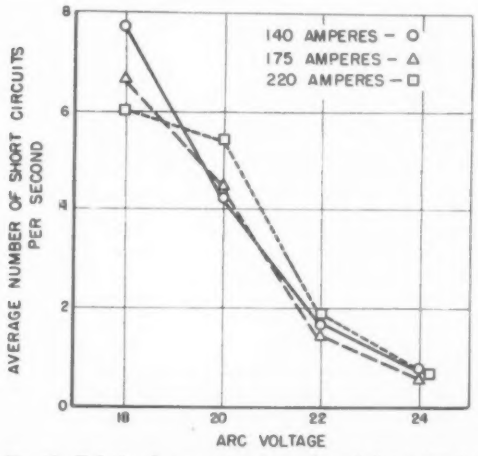

Fig. 12 Relation between total number of short circuits per second and arc voltage for a commercial $^{3}/_{16}$-in. E-6012 electrode

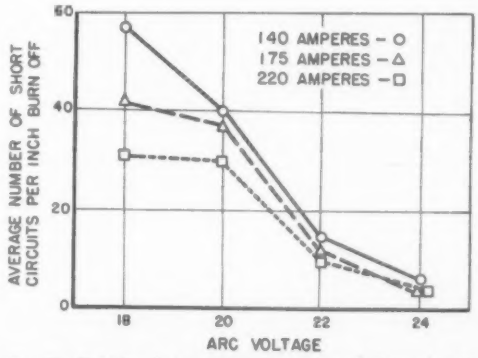

Fig. 13 Relation between total number of short circuits per inch of electrode burn-off and arc voltage for a commercial $^{3}/_{16}$-in. E-6012 electrode

of short circuits 14 millisec. or longer was also measured. The latter were directly proportional to the number of short circuits for these tests. Consequently, the total short-circuit counts are used to simplify the graphs. Figure 13 shows the test results in the terms of the number of short circuits per inch of electrode burn-off. Comparison of the figures shows that the two criteria give similar evaluations.

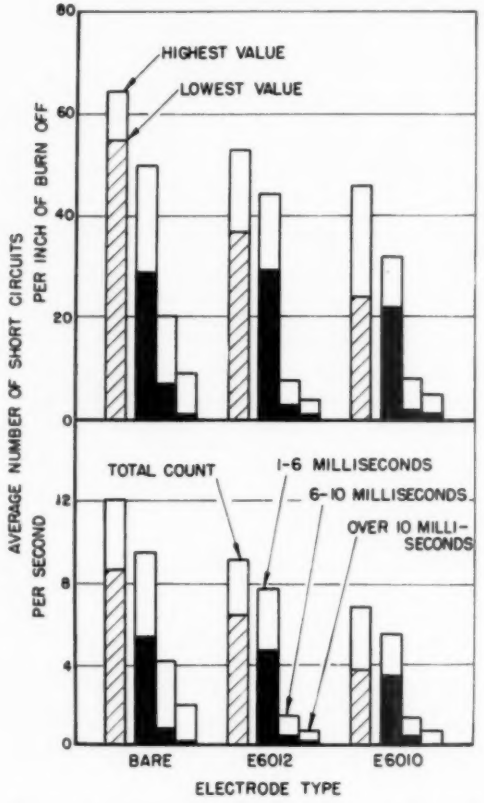

Fig. 14 Summary of short-circuit characteristics of 24 experimental wires used bare and covered. Killed-steel wires not included in wire results

As the arc voltage is increased, the number of short circuits decreases. The increasing number of short circuits with lower voltage is a natural consequence of the closer proximity of the electrode to the work when welding with lower voltages. The current magnitude seems to have little effect on the short circuit characteristics except at the lowest arc voltage. Similar results were obtained with two other types of experimental E-6012 electrodes. The results of these tests indicate that, to compare the short-circuit characteristics of electrodes of any one type, the comparison tests should be made at one voltage.

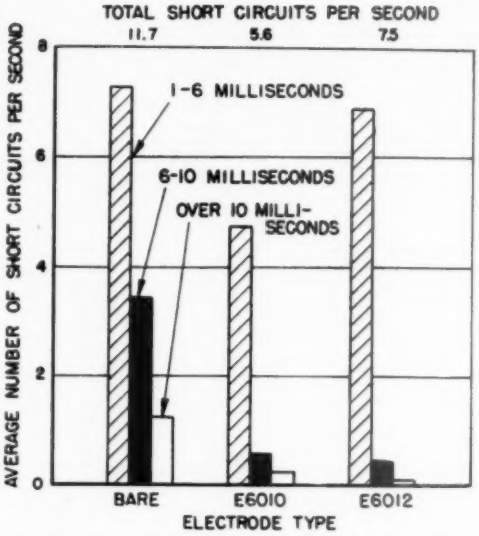

Fig. 15 Comparison of short-circuit characteristics of bare and covered electrodes from a single lot of identical core wires

Short-Circuit Characteristics of Experimental Electrodes

The short-circuit analyzer was used in welding tests with bare, E-6010 and E-6012 electrodes made with wires from the top, middle and bottom billets from selected ingots. Ten bead welds were made automatically with each electrode under the following welding conditions:

Bare wires, 18 to 20 arc volts, 180 amp.
E-6010 electrodes, 25 to 27 arc volts, 180 amp.
E-6012 electrodes, 19 to 22 arc volts, 180 amp.

The test results indicated that the core wire had little influence on the short-circuit characteristics of covered electrodes. The number of short circuits showed no correlation with the chemial composition or the microstructure (core to rim ratio, type of inclusions, etc.) of the core wire.

Figure 14 shows, however, that the type of coating had a significant influence on the short-circuit characteristics of the various types of wires. This is also shown in Fig. 15, which presents the short-circuit characteristics of one type of core wire used bare and when covered with E-6010 and E-6012 coatings. In general, the bare wire produces the most short circuits, also the longest average duration. When the wire is covered with an E-6010 coating, the number of short circuits is lower and their average duration shorter. The E-6012 covering produces an electrode with short-circuit characteristics which were intermediate between those of the bare wire and the E-6010 covered electrodes. If the wire were covered with the E-6020 coating, no short circuits occurred. These results are typical of all the core wires tested.

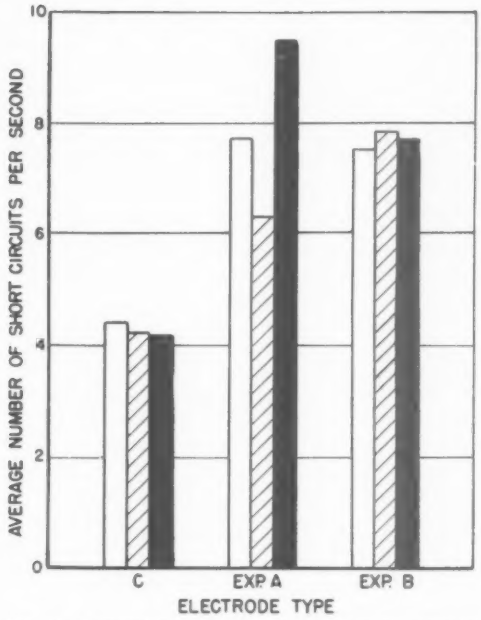

Fig. 16 Comparison of the short-circuit characteristics of a commercial E-6012 electrode and two experimental E-6012 electrodes made with the same wire. Each bar represents the average for 10 electrodes. All welding done at 20–22 arc volts and 180 amp.

The short-circuit analyzer appears to have some value in checking the consistency and uniformity of electrode coatings. Figure 16 shows the results of consistency tests made with commercial E-6012 and two experimental E-6012 electrodes made with a given core wire. The data are taken from automatic-feed weld tests made at 21–23 arc volts and 180 amp. Three groups of electrodes of each type were welded at three different times. Each bar on the graph represents the average for one group of 10 electrodes. The commercial and the experimental B electrode gave very consistent results. Experimental A electrode was inconsistent, although A and B have the same coating formulation. The two experimental electrodes differ in that A was made in a laboratory on a small extrusion press using a small batch of coating. B was made at a commercial electrode manufacturing plant on an electrode production line, using a large batch of the same coating. The more erratic results obtained with the A electrodes are attributed to differences in the coating caused by variations in mixing, extruding and drying inherent in small-batch production.

In general, the results of the test made with the short-circuit analyzer indicate that the coating on the electrode influences the various operating characteristics to a much greater degree than does the core wire.

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Influence of Consumption Rates on Flash Welding

Effect of material thickness, consumption rate, voltage current and temperature were investigated. Optimum flashing schedules have been established

by W. N. Platte

INTRODUCTION

THE flash-welding process is one of several means of joining materials electrically. Its use is indicated for repetitive butt welding operations in which only a minimum amount of metallurgical change will occur in the joined metals. Welding by this process consists of abutting the two pieces to be welded in a suitable machine and passing low voltage electrical current through the abutted surfaces. Intense local heating occurs at small point contacts between the rough abutted ends of the workpieces. These point contacts rapidly reach temperatures which are above the melting point of the parts being joined and are believed to be expelled by forces due to the expansion of internal gases, vaporization of the metal, and the magnetic field caused by passage of the welding current. The first contact point occurs at the shortest distance between the two workpieces. When this point has been expelled the separation between the pieces is locally increased and heating will occur at new contact points as the pieces are fed together.[1] This local heating and expulsion of material is referred to as flashing. As the flashing action progresses, part of the heat is dissipated from the locally heated areas into the workpiece, part is lost by radiation, and part by conduction into the welding electrodes. After sufficient material has been heated and expelled the flashing interfaces attain a uniform temperature suitable for welding and then the pieces are rapidly forced together under sufficient pressure to produce a weld. The welding current is usually interrupted at the beginning of the welding and upsetting action. After the weld is made it is allowed to cool in air and the cooling rate is not controlled, except in the case of special materials. Thus, the flash-welding process may be divided into three operations: (1) the heating stage, produced by material consumption or flashing; (2) the upsetting stage, caused by deformation under pressure; and (3) the cooling stage.

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Presented at the Thirtieth Annual Meeting, A.W.S., Cleveland, Ohio, week of Oct. 17, 1949.

Prior study of the literature disclosed poor agreement between sources of data on which flash-welding schedules can be based and consequently the need was seen for further critical study.[1] A logical approach to the investigation of the flash-welding process is to examine one stage of the process at a time. The quality of a flash weld is dependent upon the material locally reaching the proper temperature before the upsetting action occurs. Therefore, these studies pertain only to the flashing action, and extensive physical test data which would be dependent on stages (2) and (3) are not included in this paper.

Flashing was investigated by studying the effect of the following variables for each material thickness; material consumption rate, secondary voltage, secondary current, and the temperature of the work during flashing. These features were investigated by the selective variation of constant material consumption rates. In each case, the secondary or flashing voltage was started at the maximum available value and this value was reduced by means of a phase shift heat control at preselected points during the flashing period. The amount of voltage reduction was determined by the ability of the work to continue flashing after the voltage had been reduced. Thus, the lowest possible reduced voltage was the minimum voltage required to sustain flashing, at the time of voltage reduction. After a

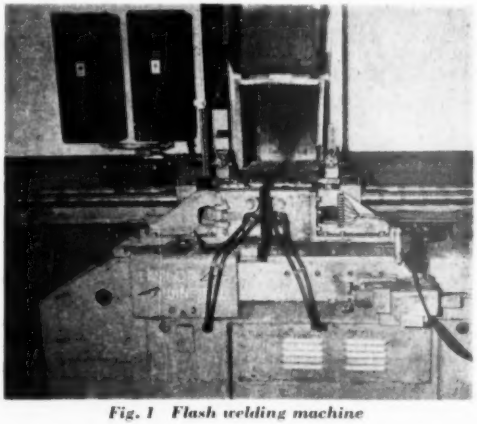


Fig. 1 Flash welding machine

further continued period of flashing the resulting increase in temperature usually makes additional reduction in voltage possible, without causing extinction of the flashing action. Reduction of the flashing voltage has the desirable effect of decreasing the size of the expelled particles and of their resultant craters on the flashing surfaces.[2] After the minimum flashing voltage was determined by trial and error methods, for each material thickness, data were taken using that voltage to simultaneously determine the corresponding current, rate of motion and work temperature.

By correlation of the data obtained, using the preceding methods, it is demonstrated that optimum flashing schedules exist and that they may be determined by direct measurement of the dynamic variables.

EXPERIMENTAL PROCEDURES

Equipment

All tests were made on a standard 150-kva. machine (Fig. 1) which operates on 440-v., single-phase, 60-cycle a.-c. current. The transformer primary is tapped so that from 2 to 6.4 secondary volts may be obtained in 16 steps. The current input to the machine is regulated by a Weld-O-trol ® electronic contactor in series with an electronic heat control, wired for a dual range of heat.

The hydraulic mechanism, used to control the machine's moving platen, is shown in Figs. 2 and 2 (*a*). The cam *A* is moved in a direction perpendicular to the valve lever *L*. Special trapezoidal cams which provided constant flashing rates were used in these tests. Each cam was designed to provide a specific amount of uniform rise from one end to the other. The total amount of rise determines the amount of material consumed in the flash-off. The flashing time is determined by the total time required for the cam *A* to move from point *D* to *E* with respect to the follower *B* (Fig. 2). This movement is controlled by a needle valve *F*. Any one of a wide range of flashing rates may be obtained from a single cam by varying the needle valve control. Three cams were used in this investigation to provide different amounts and rates of rise. The rise between points *D* and *E* were: Cam 1, 0.150 in.; Cam 2, 0.300 in.; Cam 3, 0.450 in. The travel time of the cams was varied between 26.0 sec. and 2.5 sec. By the use of the 3 cams and variable cam speeds it was possible to select any desired flashing rate from 0.006 to 0.170 in. per second and to hold that rate constant during the flashing period.

The control platen *P*, to which the cam is rigidly attached, was equipped to operate Micro Switch *C*. This Micro Switch was connected to the phase shift heat control and closing the Micro Switch made it possible to reduce the flashing voltage at any predetermined point along the control cam, that is, at any desired amount of flash-off.

An instrument panel was constructed which gave simultaneous visual readings of the line voltage, flashing current, platen motion, and the temperature of the weld

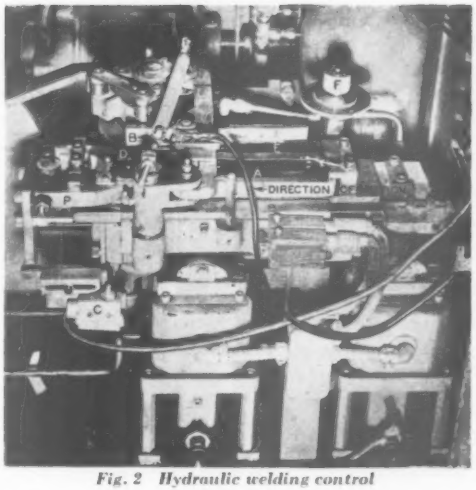


Fig. 2 Hydraulic welding control

piece of five surface locations in back of the flashing ends. The data were recorded at 0.06-sec. intervals by means of a 16-mm. motion picture camera operating at 16 frames per second. Figure 3 shows both the meter panel and the photographic equipment.

The platen motion indicator on the instrument panel was operated by a direct mechanical linkage with the movable platen. The platen linkage was fastened to a lever arm which converted any motion of the platen into motion of the indicator. The ratio of platen to indicator motion was 1:10 so that one 0.1-in. scale division on the indicator represented 0.01 in. of platen movement.

The temperature measurement meters, *T*, were 0–100 microampere meters with additional external resistance such that 54 millivolts provided a full-scale deflection when operating with chromel-alumel thermocouples. A full-scale deflection at 18 millivolts was obtained for use on platinum to platinum-rhodium thermocouples. These meters were all calibrated over the full scale using a source of emf. and a potentiometer.

Current and voltage measurements were made by using a 0–600 v. meter for line voltage, a 0–10 v. meter for flashing voltage and a 0–500 milliamp. meter with a

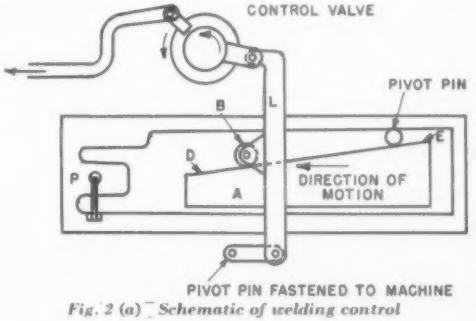


Fig. 2 (a) Schematic of welding control

current transformer for line current. The current transformer had a ratio of 200:1 so that the milliampere readings were multiplied by 200 to obtain line current and by the proper turns ratio multiplier to obtain secondary current.

Material

The material used consisted of $^1/_8$- and $^1/_4$-in. thick, low-carbon steel, hot-rolled bar stock, 2 in. wide. Only two sizes were tested; however, it is suggested that other thicknesses might be profitably investigated. The analyses of the bars used are given in Table 1.

Table 1—Chemical Analysis of Materials

Element	$^1/_8$-*in. bar,* %	$^1/_4$-*in. bar,* %
Carbon	0.059	0.141
Manganese	0.455	0.378
Phosphorus	0.006	0.009
Sulphur	0.020	0.034
Silicon	0.007	0.066

Specimens

Each sample consisted of two pieces of bar stock from which the mill scale had been removed from the welding end but not within the clamping die areas. The abrasive wheel square cut ends of the $^1/_8$-in. bar stock were used as made. The $^1/_4$-in. bar stock was prebeveled at an angle of 15° on the face of one of the two pieces to aid in starting the flashing action. An exception to this procedure was that the $^1/_4$-in. specimens used to determine the minimum initial starting voltage were not beveled. Beveling in that case would have provided a reduced section for the starting conditions and the data would not have been pertinent to the true thickness. Prebeveling has no influence upon the minimum sustainable flashing voltages once flashing has been established past the beveled end.

Welding

The first step in the experimental procedure was to flash the material at one consumption rate, starting with the maximum available voltage from the machine. On any one series of specimens the voltage was reduced, after a predetermined amount of flashing time, to a value below which flashing could not be maintained and freezing occurred. In this way, using a trial and error procedure, the minimum flashing voltage was found for the flashing rate and voltage reduction point used. Then the sample, with thermocouples attached, was placed in the machine and all data were recorded during the flashing period using the determined minimum flashing voltage for the low-voltage portion of the test. This procedure was repeated for each condition. In this particular investigation no cognizance is taken of the possible effect of flashing conditions upon the final weld properties, partially because weld properties are also related to the upset conditions. The system used to investigate temperature gradients involved 28 conditions for each material thickness and is summarized as follows:

1. Preselect a flashing rate as listed in Table 2.
2. For each of seven flashing rates, preselect a point in the flashing period at which the secondary voltage was to be reduced by the heat control. Points at 0.0, 27, 45 and 67% of the flashing period were used.
3. On a series of specimens for each flashing rate and voltage reduction point combination, progressively reduce the secondary voltage at the voltage reduction point until freezing occurs. For the voltage reduction point at 0.0% flashing time, the initial starting voltage was used throughout. No temperature measurements were taken during these preliminary trials.
4. Run a temperature-measuring test starting flashing with the maximum available voltage and reduce the voltage at the preselected reduction point to a value just above the determined

Table 2—Flashing Schedule Objectives

Code letter	*Flashing rate, in./sec.*	*Total flash-off, in.*	*Corresponding time, sec.*
A	0.006	0.165	27.5
B	0.012	0.320	26.6
C	0.018	0.480	26.6
D	0.037	0.480	13.0
E	0.062	0.465	7.5
F	0.095	0.475	5.0
G	0.170	0.435	2.5

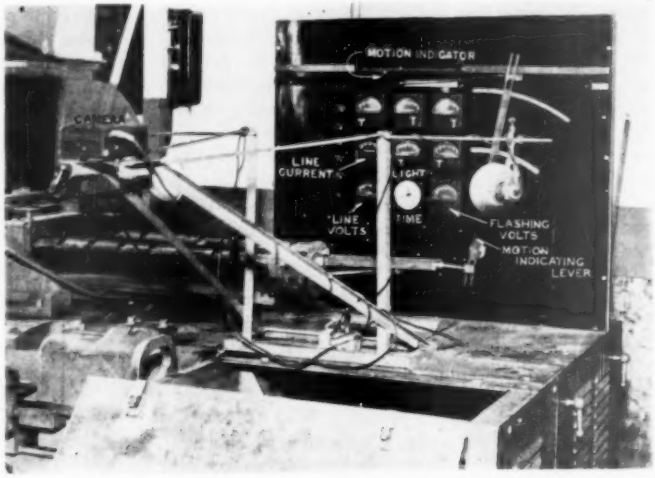
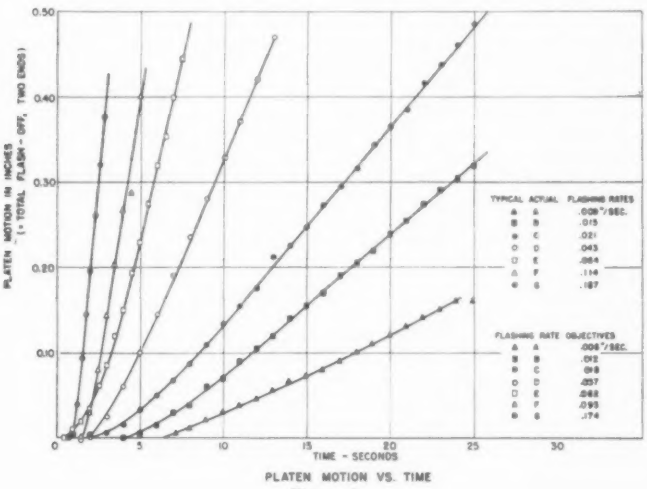


Fig. 3 Instrument Panel

freezing voltage for that point. Photographically record all data. The minimum flashing voltage was taken as the average of the freezing voltage and the lowest nonfreezing flashing voltage recorded during the pilot investigation.

5. Repeat the sequence for all the flashing rates from 0.006 to 0.170 in. per second as shown in Table 2.

In Table 2 the method of increasing the flashing rate for conditions A, B and C was to increase the total flash-off while holding the time constant. For rates D, E, F and G this process was reversed, that is, the total flash-off was maintained substantially constant and the time progressively decreased. The two systems were used to simplify filming of the data.



PLATEN MOTION VS. TIME

Figure 4

Measurement of Temperature

Either four or five thermocouples, depending on the planned amount of flash-off, were projection welded to one side of the cleaned portion of the samples at 0.1-in. intervals back from the end to be flashed. The leading thermocouple was placed 0.2 in. back of the original flashing surface on the specimens whenever the total flash-off was expected to be more than 0.2 in. This procedure prevented the leading thermocouple from being melted away. However, when the total flash-off was 0.4 in. or more, the leading thermocouple was permitted to melt off. The flashing surface moved toward the thermocouples as flashing progressed, the motion of the center of flashing activity toward the thermocouples being half the total joint flash-off. The thermocouple closest to the flashing end was of the Pt-PtRh type because of the high temperatures expected. The other thermocouples were of the chromel-alumel type.

The thermocouples were attached to their respective meters by means of a terminal block and suitable leads. As the sample was heated by the flashing action, the five microammeters indicated the side surface temperature variations up to a distance of $^1/_2$ in. back of the flashing surface during the entire flashing period.

Measurement of Flashing Rates

The true flashing rate in inches per second was obtained by using

Table 3—Effect of Location of Voltage Reduction Point for $^1/_8$-In. Bar Stock

Code	*Flashing rate, in./sec.*	*Flash-off, in.*	*Flashing time, sec.*	*Shift point on cam, in.*	*Cam travel, %*	*Minimum sustainable flashing, v.*
A	0.008	0.160	19.92	0.0	0.0	4.6
A	0.011	0.165	14.07	2.5	27.8	3.35
A	0.009	0.165	17.87	4.1	45.5	3.10
A	0.008	0.165	21.05	6.6	73.4	2.9
B	...	...	...	...	...	...
B	0.016	0.318	19.41	2.5	27.8	3.45
B	0.016	0.320	20.00	4.1	45.5	3.40
B	0.014	0.318	21.96	6.6	73.4	3.15
C	0.022	0.475	21.92	0.0	0.0	5.2
C	0.021	0.505	23.98	2.5	27.8	3.10
C	0.022	0.480	21.97	4.1	45.5	3.35
C	0.020	0.502	24.96	6.6	73.4	2.95
D	0.040	0.445	11.00	0.0	0.0	6.0
D	...	...	...	...	...	...
D	0.042	0.465	11.03	4.1	45.5	3.70
D	0.040	0.442	11.00	6.6	73.4	3.20
E	0.066	0.460	6.95	0.0	0.0	6.2
E	...	...	...	...	...	...
E	0.068	0.455	6.65	4.1	45.5	4.05
E	0.074	0.445	6.01	6.6	73.4	3.7
F	...	...	...	0.0	0.0	...
F	...	...	...	2.5	27.8	...
F	0.121	0.475	4.00	4.1	45.5	4.3
F	0.112	0.435	3.90	6.6	73.4	4.3
G	...	...	...	0.0	0.0	...
G	...	...	...	2.5	27.8	...
G	0.208	0.420	2.02	4.1	45.5	4.90
G	0.186	0.400	2.15	6.6	73.4	4.85

Table 4—Effect of Location of Voltage Reduction Point for 1/4-In. Bar Stock

Code	Flashing rate, in./sec.	Flash-off, in.	Flashing time, sec.	Shift point on cam, in.	Cam travel, %	Minimum sustainable flashing, v.
A	0.007	0.150	21.00	0.0	0.0	5.6
A	0.009	0.160	18.00	2.5	27.8	4.25
A	0.008	0.175	22.10	4.0	44.5	4.05
A	0.007	0.165	23.10	6.0	66.6	4.0
C	0.021	0.475	23.00	0.0	0.0	6.0
C	0.020	0.470	24.02	2.5	27.8	4.4
C	0.020	0.470	24.10	4.0	44.5	4.2
C	0.019	0.470	25.02	6.0	66.6	3.85
D	0.044	0.465	10.45	0.0	0.0	5.9
D	0.037	0.460	12.90	2.5	27.8	4.75
D	0.038	0.460	12.20	4.0	44.5	4.7
D	0.031	0.415	13.00	6.0	66.6	4.45
E	0.064	0.431	6.68	0.0	0.0	6.0
E	0.062	0.425	6.90	2.5	27.8	5.25
E	0.059	0.440	7.50	4.0	44.5	5.1
E	0.065	0.425	6.53	6.0	66.6	4.75
F	....	....	....	....	....	....
F	0.109	0.415	3.80	2.5	27.8	5.65
F	0.110	0.425	3.85	4.0	44.5	5.55
F	0.120	0.420	3.50	6.0	66.6	5.1

the movable platen indicator shown at the top of the control panel and the clock in the center of the bottom row of meters in Fig. 3. The motion scale indicated movement of the platen multiplied by a factor of 10. The change in position was recorded by the camera. The time required for flashing was indicated to an accuracy of 0.01 sec. by the clock. The time motion record taken by the camera made it possible to accurately determine the rate of flashing in inches per second during the entire flashing period.

After the initial starting period, the relationship between the platen and specimen motion and the motion indicated by the flashing cam was identical. Figure 4 shows motion time curves, from which it may be seen that the flashing rate is constant except at the beginning of the flashing period. The initial differences between motion indicated by the cam and the platen are due to construction of the hydraulic system of the welding machine.

Recording of Data

The data were recorded by the 16-mm. motion picture camera. The readings from every 16th frame were used except that in the case of very short flashing times every eighth frame was recorded. This arrangement gave a series of simultaneous readings on all the welding variables during the entire flashing period at 1-sec, or 1/5-sec. intervals. This method proved to be reasonably satisfactory with the relatively long flashing times involved.

Table 5—Relationship Between Minimum Flashing Voltage and Stock Thickness

Location of shift point, % of travel	Flashing rate, in./sec.	Minimum flashing voltage at reduction point for thickness of: 1/8 in.	1/4 in.
0.0	0.020	5.25	5.7
	0.100	6.2	6.2
	0.150	..	..
27.8	0.020	..	4.27
	0.100	..	5.62
	0.150	..	..
45.0	0.020	3.35	4.05
	0.100	4.18	5.55
	0.150	4.6	..
70.0	0.020	3.05	3.95
	0.100	4.16	5.85
	0.150	4.6	..

RESULTS

The essential portions of the basic data are shown in Tables 3 to 5 and 8 and 9. These data have been correlated to show the relationships existing between the following variables: the flashing rate, the flashing voltage, flashing current, work temperature, and the point of flashing voltage reduction.

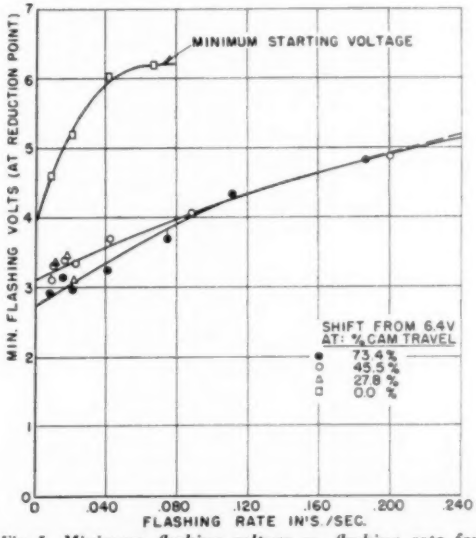


Fig. 5 Minimum flashing voltage vs. flashing rate for 1/8-in. plate at different points of voltage reduction

Table 6—Flashing Schedules

Thickness, in.	*Flashing rate, in./sec.*	*Flash-off, in.*	*Flashing time, sec.*
1/8	0.038	0.285	7.5
1/4	0.037	0.650	17.5

Table 7—A.W.S. Recommended Practices

Thickness, in.	*Average flashing rate, in./sec.*	*Flash-off, in.*	*Flashing time, sec.*
0.130	0.067	0.470	7.00
0.250	0.046	0.730	16.00

Minimum Flashing Voltage

The minimum sustainable flashing voltage at the reduction points was found for the different material consumption rates listed in Table 2 for both 1/8- and 1/4-in. steel bars. These voltage values were plotted against the consumption rate in inches per second in Figs. 5 and 6. The curves are not linear and the maximum flashing rate for a given cross section is determined by the secondary voltage employed and is limited on the upper side by the voltage available from the machine. The higher flashing rates require greater flashing voltages. The minimum sustainable flashing voltage was found to be influenced by the point in the flashing period at which the secondary voltage is reduced. Figures 5 and 6 clearly show the effect of the position of the voltage reduction point for 1/8- and 1/4-in. steel bars. These curves, and particularly those in Fig. 6, for the heavier material, indicate that the later the voltage is reduced in the flashing period, the lower will be the minimum sustainable flashing voltage.

The relationship between cross section and the minimum flashing voltage is given in Table 5. Insufficient thickness data are available to present the results in a quantitative manner but the information available indicates that the heavier section required a slightly higher flashing voltage for a given consumption rate.

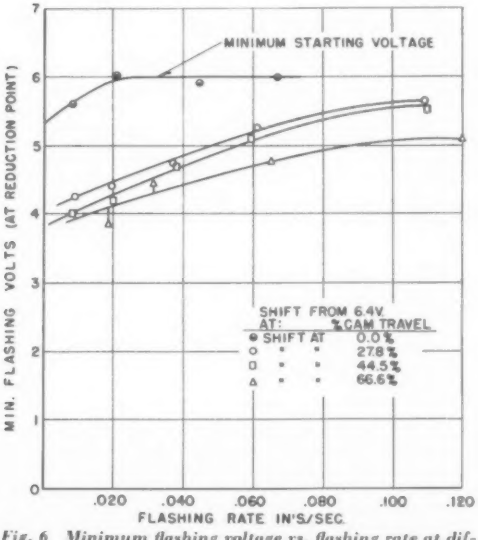


Fig. 6 Minimum flashing voltage vs. flashing rate at different points of voltage reduction, 1/4-in. plate

Table 8—Effect of Current on Maximum Extrapolated Flashing Surface Temperature for 1/8- by 2-In. Bar Stock

Voltage reduction point, % of cam travel	*Average secondary, amp.*	*Flashing rate, in./sec.*	*Maximum temperature, ° F.*
0.0	1230	0.008	2400
27.8	1160	0.011	2400
45.4	1070	0.009	2400
73.4	684	0.009	2380
0.0	1265	0.022	2200
27.8	1160	0.021	2600
45.4	1045	0.022	2600
73.4	865	0.020	2650
0.0	1730	0.040	2050
45.4	1860	0.042	2900
73.4	1715	0.040	2700
0.0	2170	0.066	2200
45.4	2210	0.068	2600
45.4	5520	0.208	2350
73.4	3420	0.186	1840

Table 9—Effect of Current on Maximum Extrapolated Flashing Surface Temperature for 1/4- by 2-In. Bar Stock

Voltage reduction point, % of cam travel	*Average secondary, amp.*	*Flashing rate, in./sec.*	*Maximum temperature, ° F.*
0.0	1865	0.007	2000
27.8	2025	0.009	2100
44.4	1960	0.008	2300
66.6	2090	0.008	2300
0.0	2590	0.021	2950
27.8	2260	0.020	2600
44.4	1845	0.019	2700
66.6	1770	0.019	2440
0.0	2850	0.044	2000
27.8	2995	0.037	2150
44.4	2670	0.038	2800
66.6	2300	0.041	2250
0.0	3240	0.067	1800
27.8	4160	0.062	1720
44.4	3830	0.059	2200
66.6	3330	0.065	1650
27.8	4220	0.109	1700
44.4	5520	0.110	1900
66.6	5130	0.120	1540

Flashing Current vs. Flashing Rate

The relation between flashing current and flashing rate for 1/8- and 1/4-in. stock are shown in Figs. 7 and 8. These curves demonstrate the changes in welding current caused by the use of maximum available flashing voltage as compared to the minimum sustainable flashing voltages for different points of voltage reduction. In all cases the required current increases as the flashing rate increases. More material is consumed per ampere at the higher than at the lower currents. The curves on which the point of voltage reduction is indicated in per cent of cam travel are based on the current drawn after the flashing voltage was reduced to the minimum sustainable voltage for the conditions used. The curve labeled "6.4 volts throughout" is based upon data taken

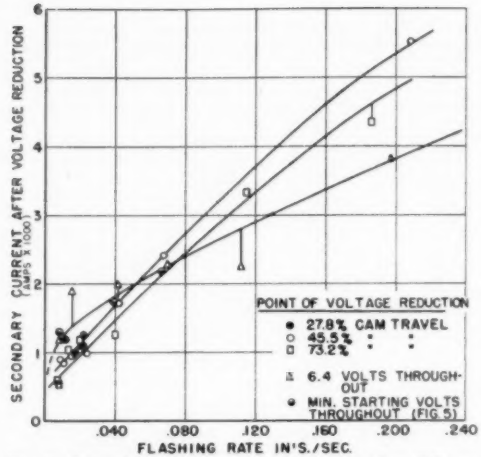

SECONDARY CURRENT AFTER VOLTAGE REDUCTION (AMPS. X 1000)
FLASHING RATE IN'S./SEC.
POINT OF VOLTAGE REDUCTION
27.8% CAM TRAVEL
45.5% " "
73.2% " "
6.4 VOLTS THROUGHOUT
MIN. STARTING VOLTS THROUGHOUT (FIG 5)

Fig. 7 Secondary current vs. flashing rate after different points of voltage reduction, 1/2-in. plate stock

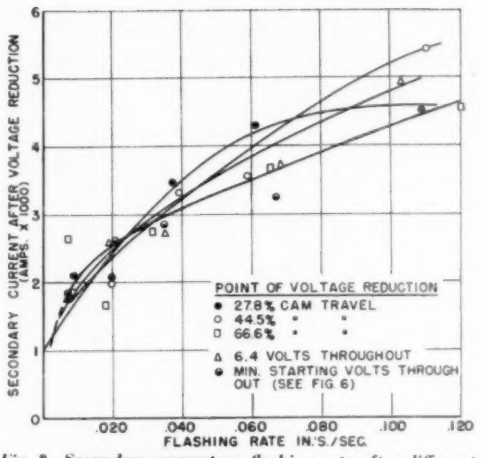

SECONDARY CURRENT AFTER VOLTAGE REDUCTION (AMPS. X 1000)
FLASHING RATE IN'S./SEC.
POINT OF VOLTAGE REDUCTION
27.8% CAM TRAVEL
44.5% " "
66.6% " "
6.4 VOLTS THROUGHOUT
MIN. STARTING VOLTS THROUGH OUT (SEE FIG 6)

Fig. 8 Secondary current vs. flashing rate after different points of voltage reduction, 1/2-in. bar stock

using the machine maximum voltage during the entire flashing period. The curve labeled "Minimum Starting Volts Throughout" is based on data using the minimum starting voltage through the entire flashing period.

A comparison of Figs. 7 and 8 shows that the required flashing current at a given flashing rate is greater for the larger cross section. However, the current density in amperes per square inch is less for the heavier stock.

Temperature Data

The temperature effect caused by the amount and time of voltage reduction, the flashing rate, and the total flash-off were obtained directly from the thermocouple

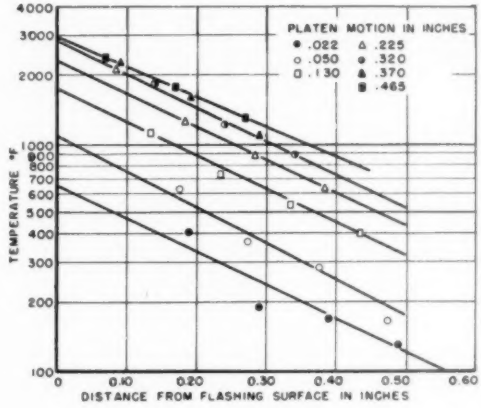


Fig. 9 (Right) Temperature vs. distance from flashing surface, 1/2-in. plate, rate 0.040 in./sec., voltage reduced at 66.6% cam movement

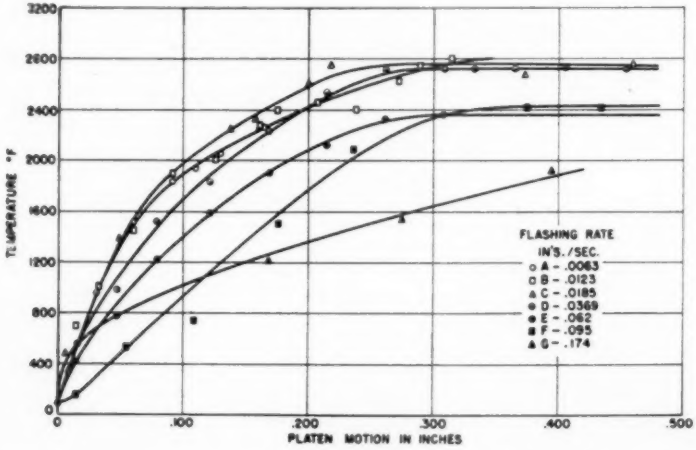


Fig. 10 Maximum projected average temperature vs. motion, 1/2-in. plate

readings. These data are given in Figs. 9 to 18, inclusive. Figures 9 and 14 show typical families of temperature-distance curves. The exponential variation of temperature with distance is clearly shown by plotting the data on semilogarithmic graphs. Figures 10 to 13 and 15 to 18 were derived by cross plotting the data taken from different distance temperature intercepts of curves similar to those in Figs. 9 and 14. The temperature of the work obtained from each thermocouple was thus used to find those flashing conditions which would provide sufficient heat to insure that the welding surfaces and adjoining metal had reached a temperature high enough for welding and upsetting.

DISCUSSION

The most important facts gained from the tests described are the interrelationships between the work temperature and the welding variables. In a completed flash weld the metal adjoining the interfaces is plastically deformed while in the hot state, immediately after termination of flashing. Knowledge of the ad-

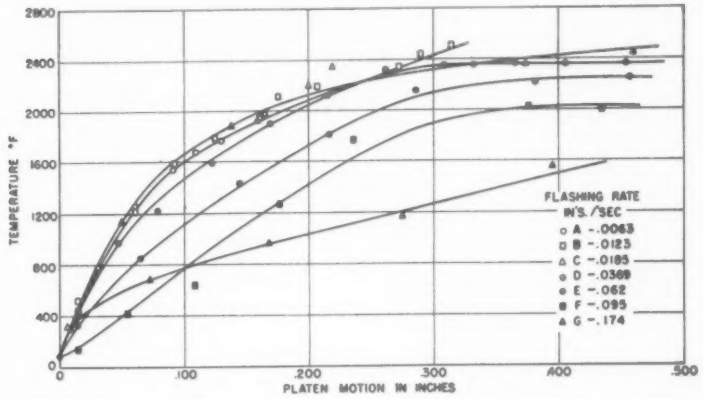


Fig. 11 Maximum average temperature 0.050 in. from flashing surface vs. motion, 1/8-in. plate

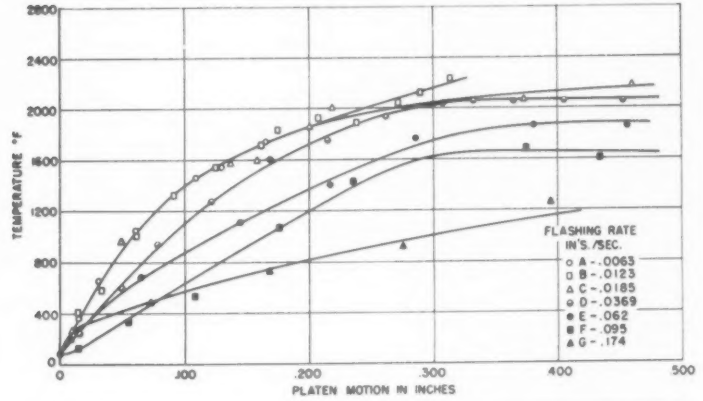


Fig. 12 Maximum average temperature 0.100 in. from flashing surface vs. motion, 1/8-in. plate

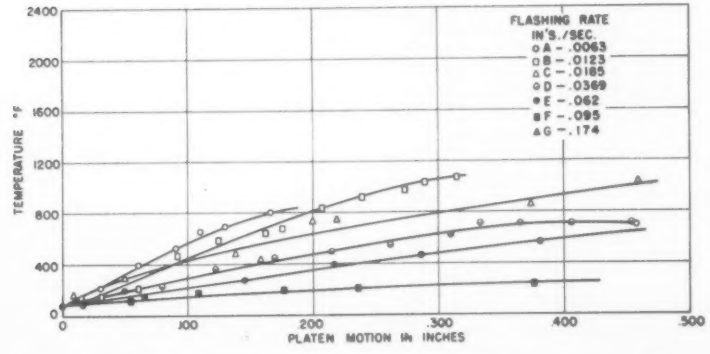
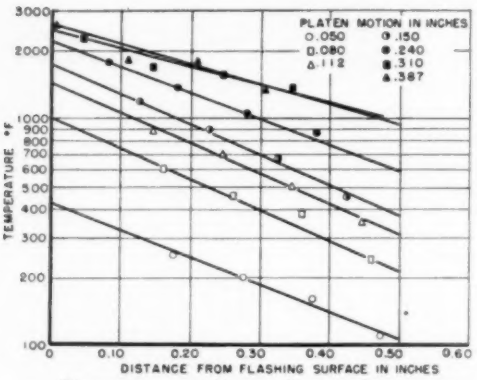


Fig. 13 Maximum average temperature 0.400 in. from flashing surface vs. motion, 1/8-in. plate

jacent metal temperature is important for that reason, since cold metal cannot be upset with the unit pressures employed in the flash-welding process. To clarify the following discussion the elementary motion-time-rate interrelationships are given here.

Platen Motion = Flashing Rate × Flashing Time.

Flashing Rate = Platen Motion ÷ Flashing Time.
Flashing Time = Platen Motion ÷ Flashing Rate.



Temperature vs. distance from flashing surface, 1/4-in. plate, rate 0.020 in./sec., shift at 27.8 per cent cam movement

Temperature Gradients

The temperature gradients back from the flashing surfaces were obtained from the thermocouple readings. Two typical sets of relationships are shown in Figs. 9 and 14 for different points in the flashing periods, indicated in terms of elapsed motion in inches. Semilogarithmic plots and projection of the temperature curves to the flashing interfaces provide an approximation of the average temperature on the flashing interface. Taking these intercepts for each of five stages in the flashing motion, and replotting temperature intercepts against motion, temperature-motion curves were obtained for 1/8- and 1/4-in. steel at various distances back from the flashing interfaces for each flashing rate. These data are shown in Figs. 10 to 13 and 15 to 18 for 1/8- and 1/4-in. plate, respectively. These curves demonstrate the existence of temperature-motion relationships for different flashing rates. The temperature-motion relationships become stable after a sufficient amount of flashing time.

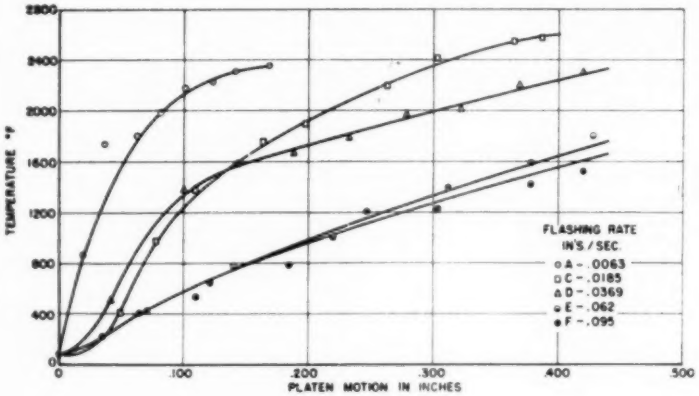


Fig. 15 Maximum projected average temperature at flashing surface vs. motion, 1/4-in. plate

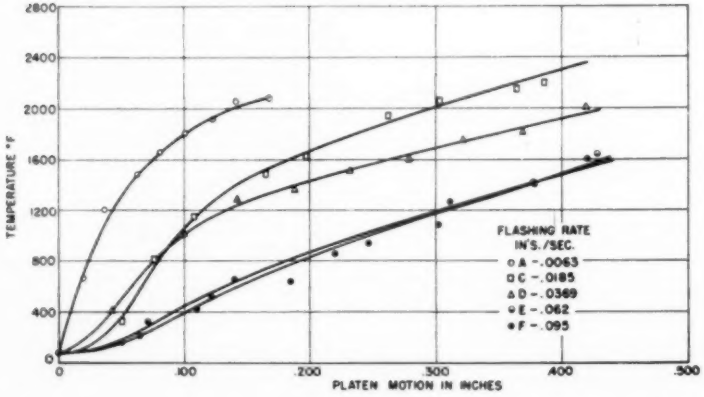


Fig. 16 Maximum average temperature 0.050 in. from flashing surface vs. motion, 1/4-in. plate

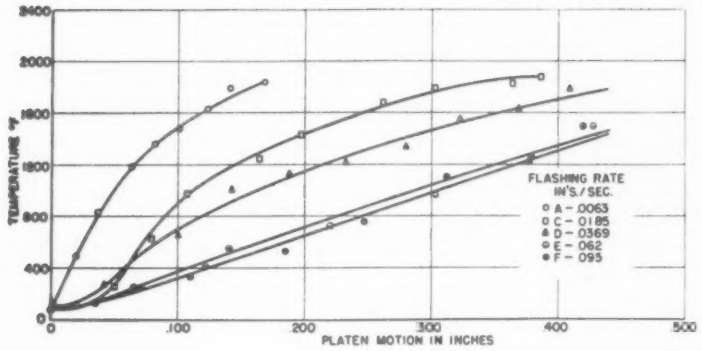


Fig. 17 Maximum average temperature 0.100 in. from flashing surface vs. motion, 1/4-in. plate

Flash-Off

The amount of flash-off, which is the same as platen motion, is shown to be an important variable with regard to the temperature of the flashing parts. It appears from Figs. 10 to 13 and 15 to 18 that if the amount of flash-off is too small for a given bar thickness and flashing rate, the parts will not reach the stable temperature-motion or temperature-distance gradient, which is indicated by the horizontal portion of the curves. Figures 10 to 13 show that for all but the highest flashing rate used, it was possible to obtain a stable temperature condition near the flashing surface, if there was sufficient flash-off. Figures 15 to 18 show that where the flash-off was not sufficient for a given plate thickness and flashing rate combination, stable temperatures could not be obtained. Steady-state temperatures are not absolutely necessary. It is necessary, however, that the weld pieces locally attain temperatures such that the material is within the forging range at the proper distance back from the flashing surface. This condition is necessary so that a proper upsetting action may be obtained.

Near the flashing end of the workpieces and during the early stages of flashing, sharp local rises of temperature apparently exist due to the formation of local bridges or electrical contacts between the workpieces.[1] These bridges are heated very rapidly due to the high current density. This localized heating condition would explain the presence of the low average extrapolated temperatures shown in Figs. 9 and 14 on a surface that appears to have been molten.

Flashing Rate

The maximum temperature attained for a given flashing program is a function of two variables, the amount of flash-off and the flashing rate. When large amounts of flash-off were used, stable temperatures were attained for all except the high flashing rates, Figs. 10 to 13. With the high flashing rates the achieved temperatures were also less than required for welding. Since finite low values of flash-off are frequently used it is possible to use flashing rates such that the maximum temperatures attained are less than the stable state temperature value. Figures 10 to 13 illustrate such conditions. For a given plate thickness and flash-off the maximum temperature attained decreases as the flashing rate increases. It is apparent from Figs. 10 to 13 that the flashing rate may be so high that the weld pieces will not reach forging temperature within a reasonable amount of flash-off. Increasing the flashing rate in inches per second decreases the achieved temperature for a given amount of flash-off in inches. This does not indicate the effect of flashing rate upon the heating rate in degrees per second.

It is shown in Figs. 19 and 20 that the average heating rate of the work in degrees per second increases as the

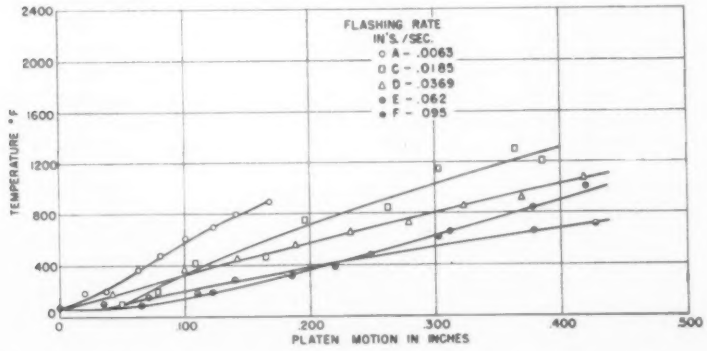


Fig. 18 Maximum average temperature 0.400 in. from flashing surface vs. motion, 1/4-in. plate

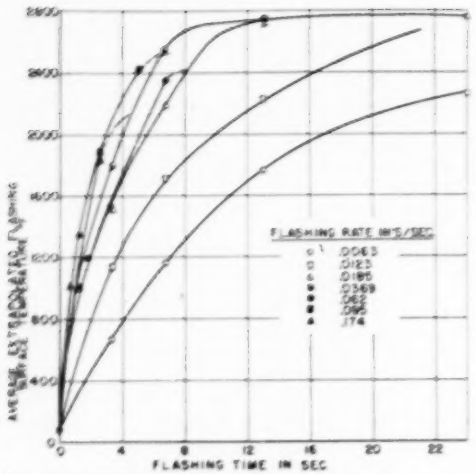


Fig. 19 Average flashing surface temperature vs. time, ¼-in. stock

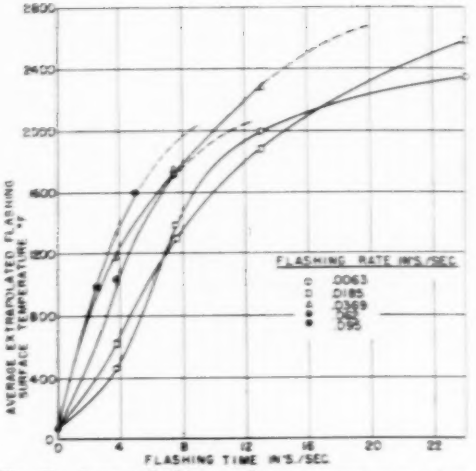


Fig. 20 Average flashing surface temperature vs. time, ½-in. stock

flashing rate increases. These curves also show that, for the early heating stages, the extrapolated flashing face temperature tends to increase almost directly with time. The observed increases in both flashing voltage and current accompanied by increased flashing rates are logical since the amount of heat put into the weld piece per second must increase as the flashing rate increases, because the material is consumed more rapidly. When the higher flashing rates are used more rapid expulsion exists and more heat per unit time is dissipated by the expelled particles into the surrounding atmosphere. An increase in the number of local contacts and expulsions per second will allow more current to flow, provided there is sufficient voltage to keep the local current density high and cause the expulsion of the contact points and thus maintain flashing.

Flashing Time

The flashing time plays an important part in determining the temperature of the weld piece at the end of the flashing period. In Figs. 10 to 13 and 15 to 18, motion can be directly converted into time in seconds by dividing the rate into the motion value and considering each curve to have a different time scale for each different flashing rate. Figures 19 and 20 show that as the flashing rate increases, the time required to reach the maximum temperature decreases or the rate of heating in degrees per second increases. However, for very rapid flashing rates, the maximum temperature of the material may be below the suitable upsetting temperature. In the case of flashing rate E (0.062 in. per second) for $^1/_8$-in. plate (Fig. 10) the material reached a stable temperature state but the maximum temperature of the flashing surface was only 2400° F. This temperature is somewhat lower than is obtained with slower flashing rates. It is possible to reach a stable maximum temperature in 7.5 to 10 sec. on $^1/_8$-in. plate at a flashing rate of 0.037 in. per second as shown in Fig. 19. Faster rates do not reach as high a temperature and slower rates require a longer flashing time. After a specific flashing time interval the heat energy losses apparently approach the electrical energy input. These observations are compatible with the standard heat equations wherein heat is a product of the second power of current and the first powers of resistance and time.

Optimum Flashing Rates

To obtain data showing that there is an optimum flashing rate for achieving a maximum temperature it is necessary to convert platen motion into time using curves similar to those in Figs. 10 and 15 and obtain data involving time, temperature and flashing rate. The curves derived in this manner (Figs. 21 and 22) show that the maximum average temperature at the flashing surface, or in back of it (Figs. 23 and 24), increases as the flashing time increases, and the temperature reaches a maximum value for some particular flashing rate. Thus, there is an optimum flashing rate for both plate thicknesses and for each flashing time studied. As the flashing time is increased the best flashing rate decreases and the maximum achieved temperature increases. This is shown by Figs. 21 to 24, inclusive.

While it is possible to reach very high average flashing surface temperatures with a low flashing rate and long flashing time, these values may not be best from an economical point of view. For example, there is little gain in heating the flashing surface 100 or 200° F. above 2700° F. if the flashing time must be doubled. The temperature range 2500–2700° F. was selected as a good average surface temperature because it is sufficiently close to the melting point for the metal to be in a highly plastic state and the adjacent metal is well within the forging range. Figure 22 demonstrates that for $^1/_8$-in. bar stock the 8-sec. flashing time curve appears to be

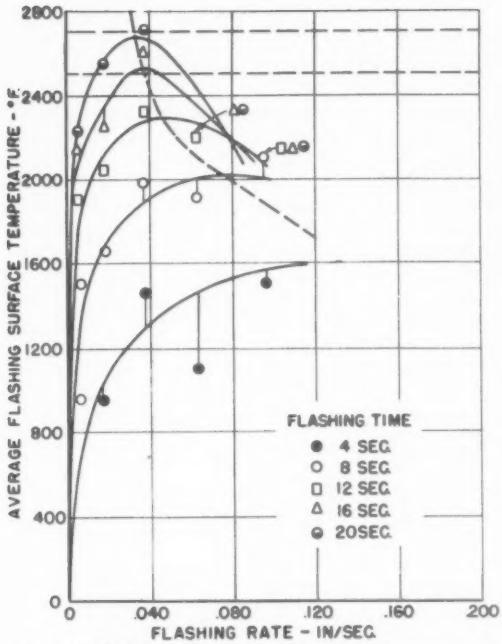


Fig. 21 Flashing rate vs. average surface temperature, 1/8-in. flat stock

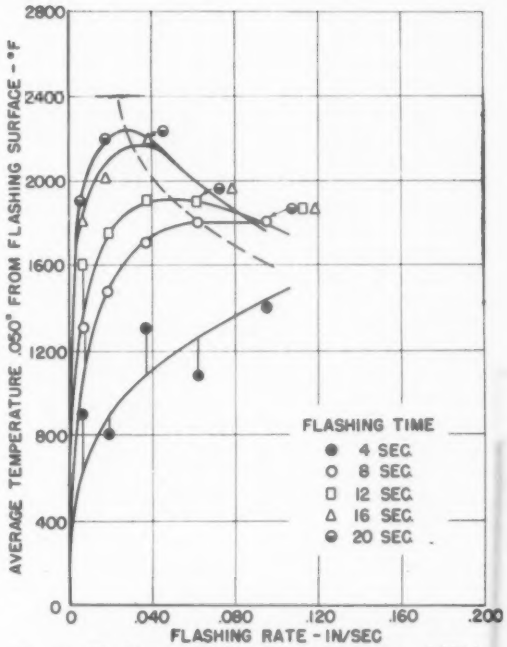


Fig. 23 Flashing rate vs. average temperature, 0.050 in. from flashing surface, 1/8-in. flat stock

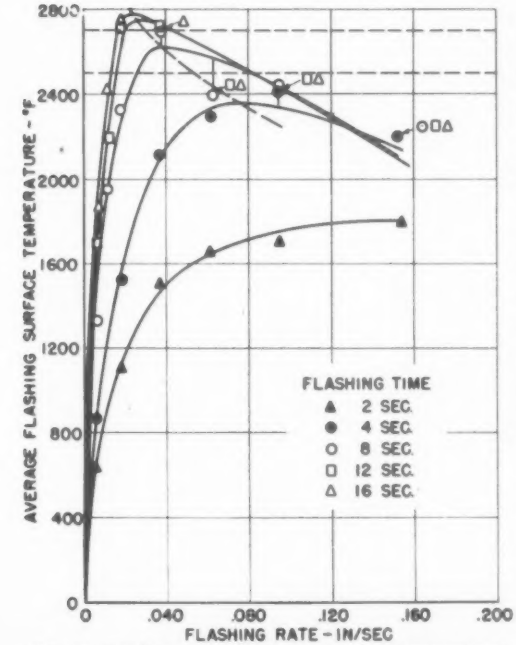


Fig. 22 Flashing rate vs. average surface temperature, 1/8-in. flat stock

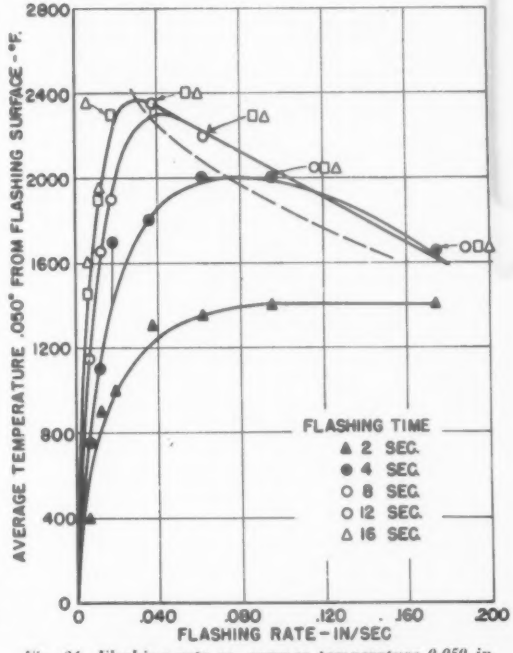


Fig. 24 Flashing rate vs. average temperature 0.050 in. from flashing surface, 1/8-in. flat stock

the best because it shows a temperature of about 2640° F. Figure 21 shows the 16-sec. curve to be best for the 1/4-in. bar since it has a maximum at about 2530° F. When both the thermal and economic factors are considered it is found that the 8-sec. flashing time may be applied to the 1/8-in. plate. The curve in Fig. 22 shows that the optimum flashing rate required to attain the maximum temperature in 8 sec. is from 0.035 to 0.040 in. per second. The 16-sec. curve in Fig. 21 also shows the optimum flashing rate to be from 0.035 to 0.040 in. per second. Figures 23 and 24 confirm Figs. 21 and 22 by showing a maximum in temperature and time economy at the same flashing rate for reoccurring maximum temperatures 0.05 in. back of the flashing interfaces. When the flashing rate and time have been established the amount of flash-off may be set from the time-distance factors. Thus a complete optimum flashing schedule may be established from the data in Figs. 21 to 24. These flashing schedules for 1/4- and 1/8-in. flat bars are given in Table 6. An average surface temperature of 2600° F. was used to establish these schedules.

Flash welds made using the optimum schedules given in Table 6 are shown in Fig. 25. Standard A.W.S. upset values were used for these specimens. The optimum values for the flashing rate and time may be explained if the thermal conditions are taken into consideration. At low flashing rates the current is low but the flash particles are not expelled as rapidly, allowing greater time for heat dissipation into the weld piece. As the flashing rate increases the current increases but the effect of the increased rate of metal expulsion and the lack of dissipation time becomes greater than the resistance heating effect of increased flashing current.

The American Welding Society Resistance Welding Standards, for flashing 1/8- and 1/4-in. low-carbon steel, are given in Table 7. In comparing Tables 6 and 7 it is obvious that the A.W.S. standards employ a larger amount of flash-off at a higher flashing rate. Both procedures would be expected to provide about the same temperature.

Temperature Voltage Effects

The point at which the welding voltage was reduced

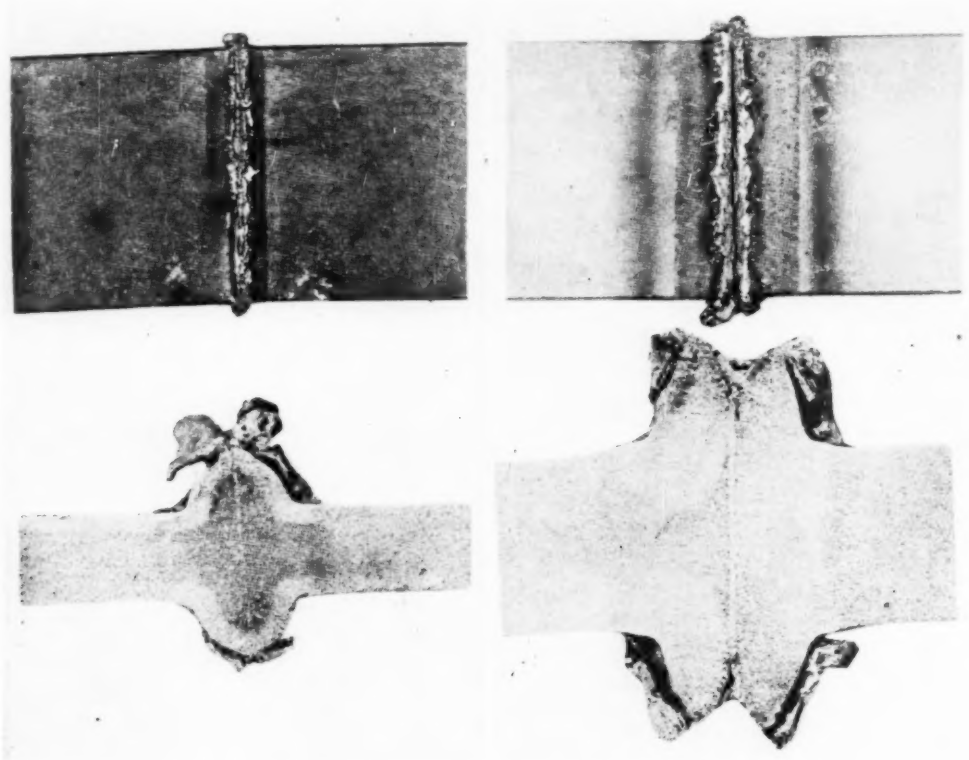


Fig. 25 Welds made using optimum flashing conditions

1/4- x 2-in. bar
Tensile strength, 57,500 psi.
Parent metal strength, 58,500 psi.
Ruptured outside of weld

1/4- x 2-in. bar
Tensile strength, 51,200 psi.
Parent metal strength, 50,000 psi.
Rupture outside of weld

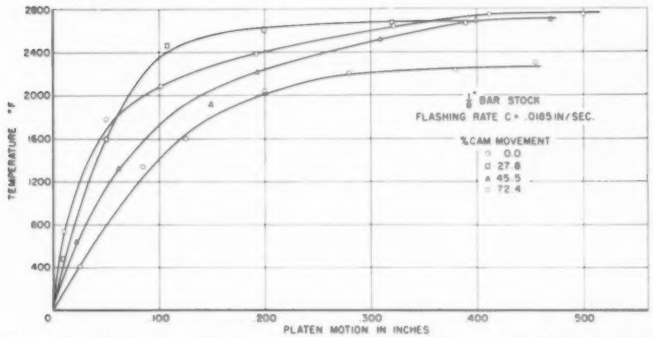


Fig. 26 Maximum average surface temperature vs. motion. Voltage reduction at given per cent of cam movement

by the phase shift heat control appears to have some effect upon the temperature of the weld piece, as shown in Fig. 26. Apparently at least two other variables besides the point of voltage reduction affect the temperature motion curves for a given point of voltage reduction. These two variables are the average current and voltage over the entire flashing period. Larger average currents appear to cause higher temperatures for a given amount of flash-off. As the point of voltage reduction is changed to positions late in the flashing period the average current tends to decrease while the average voltage will increase. Tables 8 and 9 show the average current values and the maximum temperatures attained. These data are only qualitative in nature and indicate the way in which current values may influence the temperature data.

There is a close relationship between temperature of the flashing surface and the minimum required flashing voltage. As temperature of the work increases, the required voltage decreases. The graphical presentation of this relationship is shown in Figs. 27 and 28. The change of the minimum flashing voltage with an increase in the temperature of the work may be partially explained by the fact that less heat input is necessary to maintain flashing after the weld pieces are hot. For example, if the weld pieces are at 1800° F. only enough heat need be added to raise the temperature another 950° F. before it becomes molten. Thus, less total heat input would be necessary when the piece is at 1800° F. than if it were at room temperature. Lowered heat requirements mean less current. Since the current can be reduced the voltage may be reduced and flashing still be maintained.

SUMMARY

The variables involved in the flashing portion of the flash-welding process are the flashing rate, time, voltage, and current. Definite interrelationships have been found to exist between these variables. The voltage required to maintain flashing has been found to be a function of the material consumption rate and the workpiece temperature. The current required at a voltage just above the minimum to maintain flashing has been shown to be dependent upon the flashing rate.

The temperature of the workpieces was found to be a function of the flashing rate and time. An optimum rate and time of flashing was found to exist which would provide a maximum temperature in the workpieces. The optimum values were used in conjunction with the values for the required voltage to establish optimum welding conditions. Welds having satisfactory physical properties have been made using these optimum values.

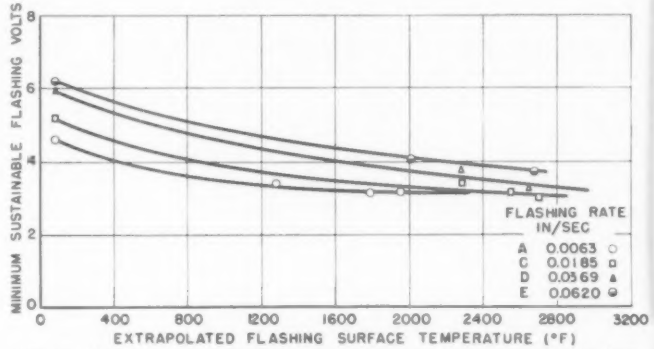


Fig. 27 Minimum sustainable flashing voltage vs. temperature, 1/4-in. bar

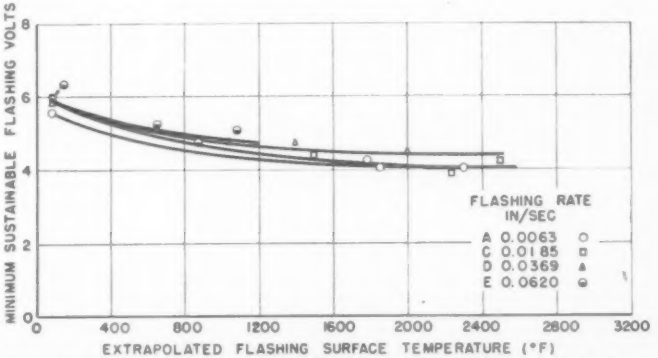


Fig. 28 Minimum sustainable flashing voltage vs. temperature, 1/4-in. bar

CONCLUSIONS

1. The minimum permissible flashing voltage is a function of the flashing rate, dimensions of the parts, and the temperature of the weld pieces.

2. The minimum required flashing voltage increases as the flashing rate increases and decreases as the temperature increases.

3. The effect of the flashing rate upon the minimum sustainable flashing voltage is predominant over the effect of work temperature on that voltage.

4. The required flashing current increases as the flashing rate increases.

5. The temperature attained by the weld pieces depends upon the flashing rate and the total flashing time.

6. The rate of temperature increase depends upon the flashing rate.

7. The best operating rate may be defined by the maximum in the temperature vs. rate curve attained when the flashing rate is increased for a given flashing time and cross section.

8. Future work involving upset variables may be aided by the use of optimum flashing rates.

9. Optimum flashing schedules may be established using optimum flashing rate and time data in conjunction with the minimum flashing voltage for the rate used.

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2. Riley, J. J., "Flash-Butt Welding," The Welding Journal, 24 (1), Research Suppl., 12-s to 24-s (1945).

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Tests of Specimens Simulating Weld Heat-Affected Zones

The application of a time-temperature control device for the investigation of the impact properties of weld heat-affected zones

by Ernest F. Nippes and Warren F. Savage

Summary

A time-temperature control device was previously designed which would permit exact duplication of the heating and cooling cycles established by a readily made cam. Using information obtained from previous studies of time-temperature relationships near an arc weld, suitable cams were made to duplicate several of the heat-affected structures associated with arc welds in $^1/_2$-in. aluminum-killed steel plate. The time-temperature control device was employed to produce specimens of each structure for impact testing. The results of Charpy-Izod impact tests on each of the structures were presented and discussed. Suitable photomicrographs were presented as explanations for some observed properties. A region exhibiting abnormally low impact properties was discovered well outside the normally considered heat-affected zone of an arc weld. The observed properties in this region were attributed to a strain-aging reaction.

INTRODUCTION

THIS research represents a systematic investigation of the impact properties of some of the metallographic structures produced by the making of an arc weld in steel. The method of attack being unique, a brief consideration of the features will be contained here for purposes of clarification.

The basis for this method of investigation of the impact properties of the microstructures produced in the neighborhood of an arc weld may be summarized as follows:

1. Since the sloping nature of the heat-affected zone of an arc weld prohibits the making of a significant determination of the impact properties of the individual microstructures directly, a new method of investigation was decided upon.
2. Investigation of the time-temperature relationships in the neighborhood of an electric arc weld, previously performed by Nippes, Merrill and Savage,[1] made possible the quantitative prediction of the time-temperature cycle experienced by any point in the neighborhood of an arc weld. The results of this investigation were employed in the present research to obtain the heating and cooling cycles at various points near arc welds in $^1/_2$-in. steel plate.
3. By subjecting specimens to the exact time-temperature cycle found at a point, the microstructure found at that point near an arc weld was duplicated in the specimen. This duplication of the time-temperature cycle, and hence duplication of the structure, was carried out with the aid of the time-temperature control device described in a previous report.[2]
4. By this method, metallographically identical specimens could be prepared by means of the time-temperature control device. This permitted determination of the impact properties of a given structure, as a function of the testing temperature.
5. A suitable cam could be constructed to permit duplication of any of the microstructures found near an arc weld.
6. In this fashion a thorough investigation could be made of the impact properties of each of the characteristic microstructures found in the neighborhood of an arc weld.

MATERIAL AND EQUIPMENT

All the necessary specimens for impact testing were prepared using the time-temperature controller described previously.[2]

The steel employed for the present investigation was produced to satisfy the requirements of A.S.T.M. Specification A-201, and was aluminum killed. This steel was manufactured especially for the Pressure

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Presented at the Thirtieth Annual Meeting, A.W.S., Cleveland, Ohio, week of Oct. 17, 1949.

Vessel Research Committee, and was obtained from this group in the as-rolled condition, 5/8 in. thick. The chemical analysis was as follows:

	%
C	0.16
Mn	0.53
Si	0.20
P	0.012
S	0.024
Ni	0.04
Cr	0.02
Mo	0.01
Cu	0.06

The mechanical properties of the steel were determined to be as follows:

Ultimate tensile strength, psi.	63,300
Yield point, psi.	40,700
% Elongation in 2.00 in., %	31

All impact testing was performed using a Riehle Combination Impact Testing Machine, serial R12889. Metallographic studies were prepared using a Zeiss Neophot Research Metallograph, serial 275277.

PROCEDURE

Selection of Conditions

It was decided to investigate the impact properties of the microstructures listed in Table 1.

The method of determination of the corresponding heating and cooling cycles for microstructures in Table 1 is contained in Appendix I. Tables 1 through 11 of Appendix I contain the necessary information for the production of cams required to produce each of the microstructures of series 1 to 11, respectively.

It was decided to investigate the microstructures represented by series 1, 2, 3 and 9 as a result of some curious anomalies reported by Martini[3] in an undergraduate thesis involving a metallographic investigation of arc welds made in this same steel. Discontinuities in the hardness traverses made on welds of three different energy inputs were reported by Martini in regions where the steel at no time experienced temperatures in excess of the effective A_1 transformation temperature. This information was considered to be of sufficient importance to bear further investigation.

Table 1—Plate thickness, ½ in.; initial plate temperature, 72° F.

Series No.	*Corresponding energy input, joules/in.*	*Maximum temperature experienced during the production of microstructure, ° F.*	*Distance of particular microstructure from center line of arc weld, in.*	*Nature of structure*
1	70,000	700	0.935	Strain-aged
2	70,000	950	0.625	Strain-aged
3	70,000	1150	0.519	Strain-aged
4	70,000	1350	0.460	Spheroidized
5	70,000	1450	0.436	Partially refined
6	70,000	1650	0.398	Refined
7	70,000	1850	0.374	Refined
8	70,000	2100	0.353	Coarsened
9	37,500	912	0.400	Strain-aged
10	52,500	1370	0.379	Spheroidized
11	52,500	1470	0.366	Partially refined

Preparation of Specimens

Specimens 0.4 x 0.4 x 3 in. were machined from 5/8-in. plate of the aluminum-killed steel. Specimens were machined with the 3 in. dimension parallel to the direction of rolling, and an identifying mark was placed on each specimen to indicate the faces parallel to the original rolled surfaces. As shown in Fig. 1, a 0.052-in. diameter hole was drilled to a depth of 0.052 in., on a face perpendicular to the original rolled surfaces, in the center of the 3 in. dimension.

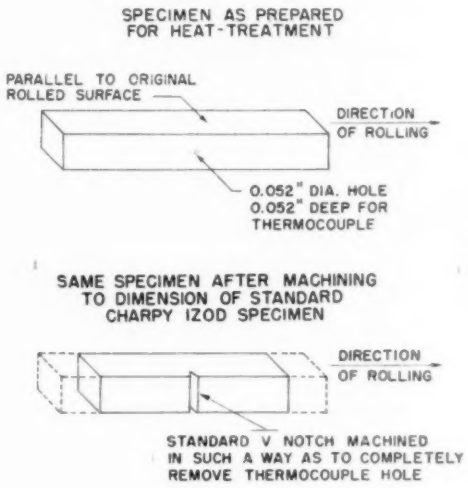
SPECIMEN AS PREPARED FOR HEAT-TREATMENT
PARALLEL TO ORIGINAL ROLLED SURFACE
DIRECTION OF ROLLING
0.052" DIA. HOLE 0.052" DEEP FOR THERMOCOUPLE
SAME SPECIMEN AFTER MACHINING TO DIMENSION OF STANDARD CHARPY IZOD SPECIMEN
DIRECTION OF ROLLING
STANDARD V NOTCH MACHINED IN SUCH A WAY AS TO COMPLETELY REMOVE THERMOCOUPLE HOLE

Figure 1

Thermocouples were made using 0.010-in. diameter Chromel and Alumel wires. A ceramic tubing approximately 0.10 in. in diameter and 12 in. long, having two parallel holes 0.015 in. I.D. running parallel to the 12 in. dimension, was employed for insulation of the two thermocouple wires from one another. A 2-in. length of glass tubing, drawn to fit the 0.010-in. diameter wire snugly, was employed on each wire to extend the insulation to the hot junction. The hot junction was made by cross-wire welding the Chromel to the Alumel at a 60° angle, using a Raytheon, bench type, condenser-discharge welder. The overlapping ends of the wires were carefully trimmed to produce essentially a point contact hot junction.

The specimens were next clamped in the jaws of the flash welder one at a time, and a thermocouple welded in position at the bottom of the 0.052-in. hole in that specimen. The specimen was carefully centered so that the hole was located midway between the jaws of the flash welder. A bank of condensers of 150 microfarads, charged to 500 v., was employed to flash the

thermocouple in place. A properly installed thermocouple was found to be so firmly attached as to cause breakage of the 0.010-in. diameter wires without pulling them loose from the specimen. A good thermal contact was therefore assured by this method of attaching the thermocouples.

Using an appropriate cam with the cam-operated potentiometer, the time-temperature control device was then employed to produce several identical specimens for each of the eleven series listed in Table 1. The procedure described above was repeated for each specimen of a series until sufficient specimens were obtained for impact testing.

Metallographic examination of specimens heat treated by means of the time-temperature control device revealed no detectable variation in microstructure over the cross section of the specimen. In addition, with the 0.70 in. clamping distance employed, a region of approximately 0.10 in. on either side of the control thermocouple location exhibited similar uniformity in a longitudinal direction. It is to be understood, however, that a reduction in the free length of the specimen, as clamped in the jaws of the flash welder, will reduce the breadth of this region of metallographic uniformity.

As a check on the operation of the time-temperature control device, a current record was obtained using the Brush Direct Inking Oscillograph, previously described.[2] Irregularities in the operation of the control device, apparent in the resulting record were considered sufficient grounds for discarding a specimen. Only when the amplified unbalance signal appearing on the cathode-ray oscilloscope, and the current record obtained by the Brush Oscillograph indicated satisfactory operation of the control, was a specimen saved for testing. Most rejections due to improper operation could be traced directly to faulty welding of the thermocouples to the specimen. The over-all loss due to all causes averaged somewhat less than 10% of the some 150 specimens produced.

Testing Procedure

Charpy-Izod specimens were employed throughout the investigation to obtain an index of the notch toughness of the various microstructures. The specimens, previously described, were subjected to the appropriate heating and cooling cycle, and then surface ground to finish dimension. The 0.052-in. diameter hole drilled for the thermocouples was used as an index for the notching operation. The standard Izod notch was machined in such a way as to be centered on the thermocouple hole, and the thermocouple hole thus was completely removed by the machining operation as indicated in Fig. 1. This left the root of the Izod notch located immediately below the point at which the thermocouple was attached.

Charpy-Izod specimens were tested over the range of testing temperature from −63 to 200° F., in order to observe the transition from brittle to ductile failure. The testing temperatures were attained by immersion of the specimen in a suitable liquid medium maintained

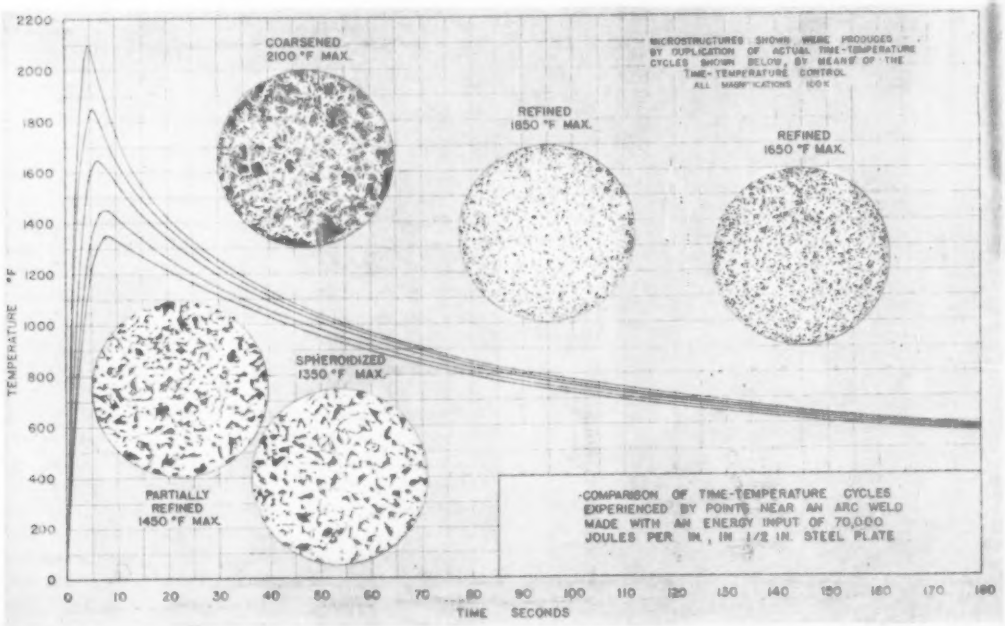

Figure 2 (4) Reduced by 1/2 in reproduction

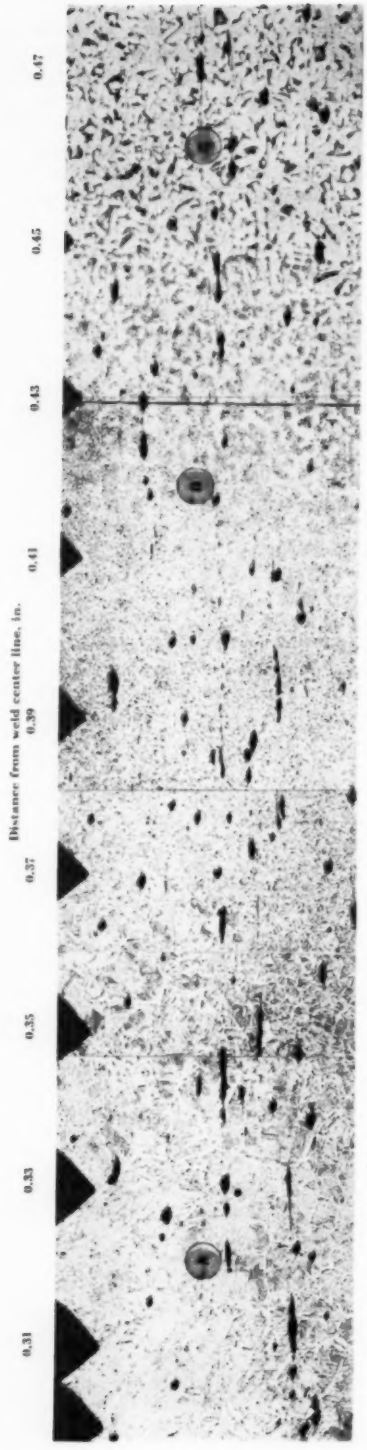

Fig. 2 (B) Panorama showing microstructures associated with an arc weld made in 1/2-in. plate using an energy input of 70,000 joules per inch. 50 ×

at the required temperature. The maximum time required for a specimen to attain thermal equilibrium with the liquid medium was determined by means of high-speed temperature recording equipment[4] over the range of temperature used. Although this maximum time was found to be approximately 4 min., specimens were held in the bath 15 min. to insure ample time for thermal equilibrium to be reached.

Alcohol was used as the liquid medium for all tests below room temperature. The temperature of the alcohol was maintained in an insulated vessel by the addition of dry ice. An image of a narrow slit was focused at the center of the opening between the jaws of the testing machine, to allow rapid centering of the impact specimen. With the aid of this rapid centering procedure, completion of the impact test could be accomplished within 5 sec. after the instant of removal from the bath. The surface temperature rise of the impact specimen associated with this time interval was determined by the use of high-speed temperature-recording equipment. The maximum rise was found to be only about 2° at −60° F. and was therefore neglected, since the error in measurement of bath temperature was considered to be ±1° F. in this range.

A bath of water maintained at testing temperature on an electric hot plate was used for all elevated temperature testing. A temperature correction, experimentally determined, was applied to account for the drop in temperature experienced when testing from a bath maintained at above 140° F. The magnitude of this correction was determined by the elapsed time between removal of the specimen from the bath and the moment of impact.

RESULTS AND THEIR INTERPRETATION

Verification of the Method

Figure 2 (*A*) compares five different time-temperature cycles experienced by points in the neighborhood of an arc weld made in 1/2-in. plate, using an energy input of 70,000 joules per inch. The photomicrographs shown in Fig. 1 were obtained from the specimens prepared by using the time-temperature control device to duplicate these time-temperature cycles. All photomicrographs in Fig. 2 (*A*) were taken at 100 × magnification in order to permit comparison with the corresponding structures produced by the actual arc weld, shown in Fig. 2 (*B*) taken from a previous report.[2]

Comparison of the microstructures produced by duplication of the predicted time-temperature cycles with those found at the corresponding distance from the center line of the actual weld confirms the validity of the method. The photomicrographs shown in Fig. 2 (*A*) are labeled according to the maximum temperature attained. The structures shown were produced to correspond to those found at the following distances from the center line of the arc weld shown in Fig. 2 (*B*). For example, compare the microstructure of Series 11, labeled 2100° F. max., produced by duplication of the

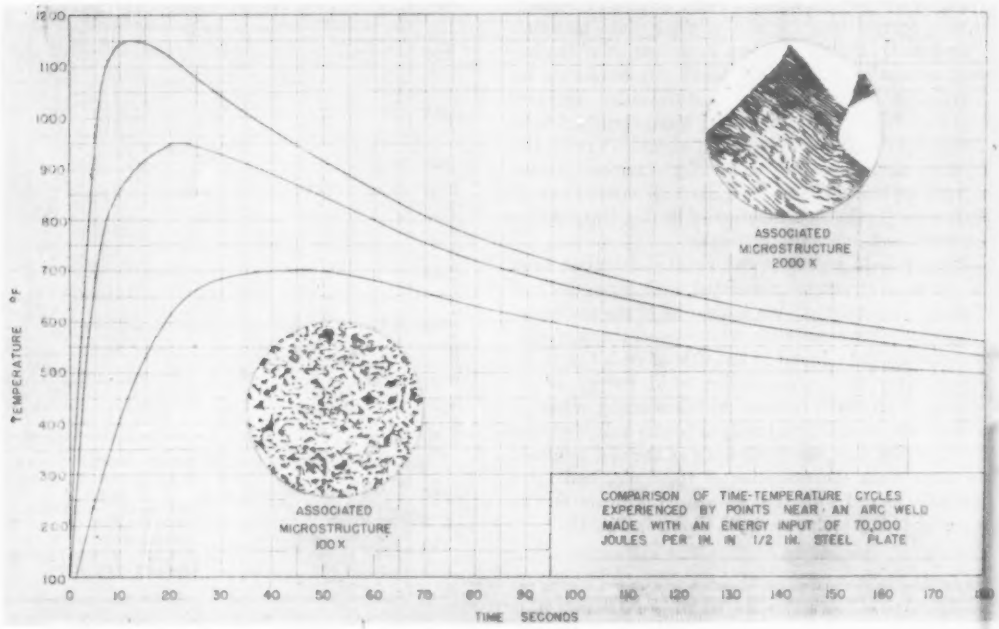
TEMPERATURE °F
TIME SECONDS
ASSOCIATED MICROSTRUCTURE 2000 X
ASSOCIATED MICROSTRUCTURE 100 X
COMPARISON OF TIME-TEMPERATURE CYCLES EXPERIENCED BY POINTS NEAR AN ARC WELD MADE WITH AN ENERGY INPUT OF 70,000 JOULES PER IN. IN 1/2 IN. STEEL PLATE

Figure 3

required heating and cooling cycle in a specimen, to the actual microstructure found at a point 0.353 in. from the center line in Fig. 2 (*B*).

Microstructure labeled, ° F., max.	*Predicted distance from weld center line to corresponding structure, in.*
2100	0.353
1850	0.374
1650	0.398
1450	0.436
1350	0.460

It should be noted that all of the microstructures shown in Fig. 2 (*A*) were the result of at least some degree of austenization, with the possible exception of the spheroidized material, which is a border-line case.

Figure 3 shows three additional time-temperature cycles, none of which produced any austenization. As was expected, no change in the metallographic structure was produced which could be detected by microscopic examination. Microscopic examination showed no recognizable differences between any one of the structures produced by these three time-temperature cycles and the structure of the original plate material. Photomicrographs at 100 × and 2000 × magnification are included as confirmation of this fact in Fig. 3. It will be noted that the structure shown (in this case the one produced by the time-temperature cycle of maximum temperature 1150° F.) is the usual ferrite and pearlite structure associated with a steel of this carbon content

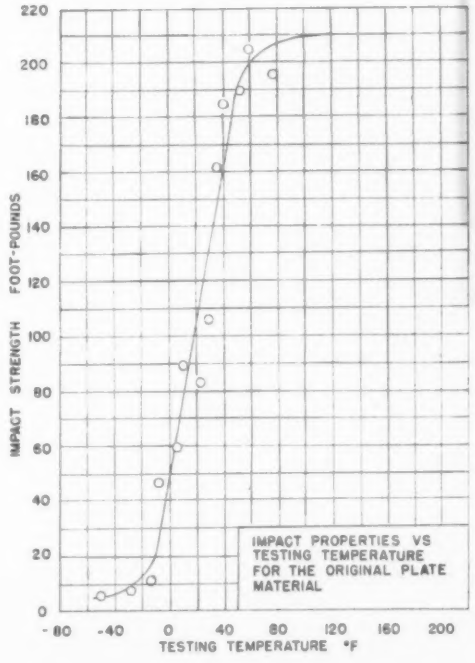
IMPACT STRENGTH FOOT-POUNDS
TESTING TEMPERATURE °F
IMPACT PROPERTIES VS TESTING TEMPERATURE FOR THE ORIGINAL PLATE MATERIAL

Figure 4

Figure 4 shows the impact properties as a function of testing temperature for the original plate material. This data is obtained from an investigation of the impact properties of this steel, previously conducted by Martini[3] in this laboratory. The transition temperature from brittle to ductile failure was determined to be 21° F. by the slope method, and about 29° F. by the fracture method.* This curve of the impact properties will be included for reference on all curves showing impact properties as a function of testing temperature for weld heat-affected structures.

Figures 5–15 represent the results of impact tests of the microstructures associated with series 1–11 of Table 1, respectively. An indication of the maximum temperature attained in the production of the particular structures will be found in the title of each figure, together with the corresponding weld energy input. Wherever practical, further identification by reference to the type of structure involved is also indicated. It will be noted that the consistency of the test results is excellent, with the exception of those obtained for a partially refined structure associated with an energy input of 52,500 joules per inch, shown in Fig. 15.

* All transition temperature determinations were accomplished by tw methods: (1) The slope method—the temperature of transition from ductile to brittle fracture was determined as the mid-point of the steep drop in the curve of impact strength as a function of testing temperature; (2)the fracture method—the temperature of transition from ductile to brittle fracture was assumed as that testing temperature which resulted in a fracture exhibiting the typical crystalline fracture appearance over approximately one-half of its area.

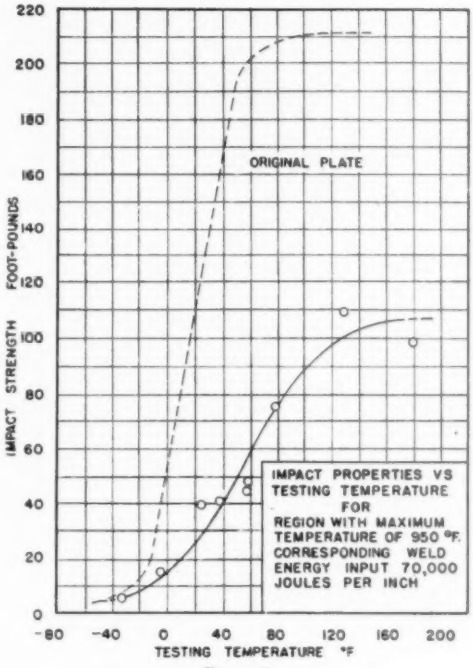

Figure 6

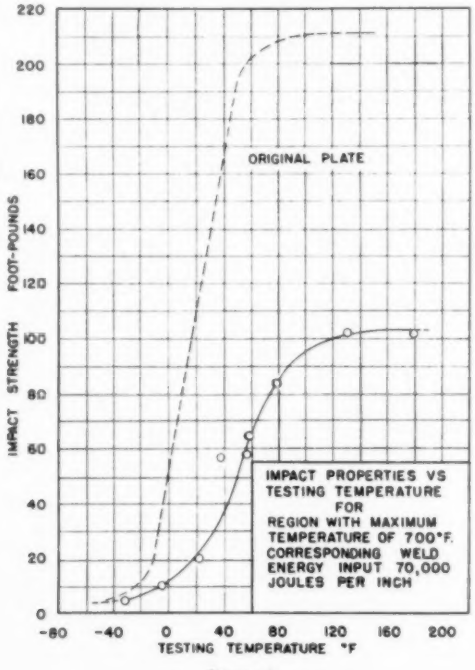

Figure 5

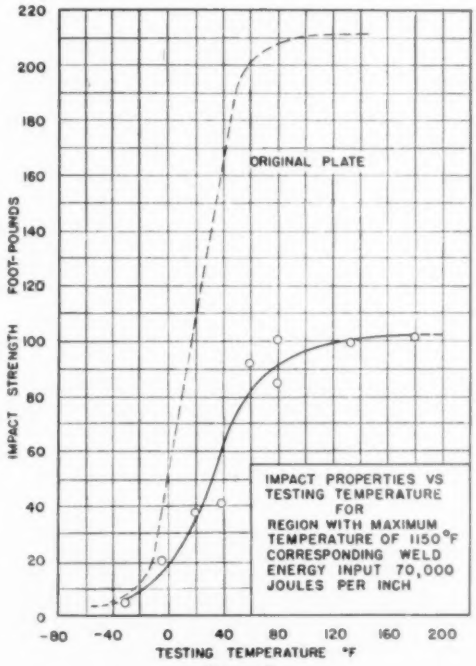

Figure 7

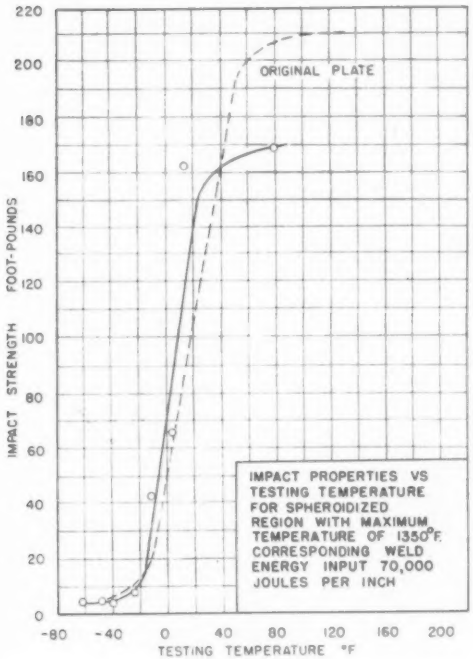
ORIGINAL PLATE
IMPACT PROPERTIES VS TESTING TEMPERATURE FOR SPHEROIDIZED REGION WITH MAXIMUM TEMPERATURE OF 1350°F. CORRESPONDING WELD ENERGY INPUT 70,000 JOULES PER INCH
IMPACT STRENGTH FOOT-POUNDS
TESTING TEMPERATURE °F

Figure 8

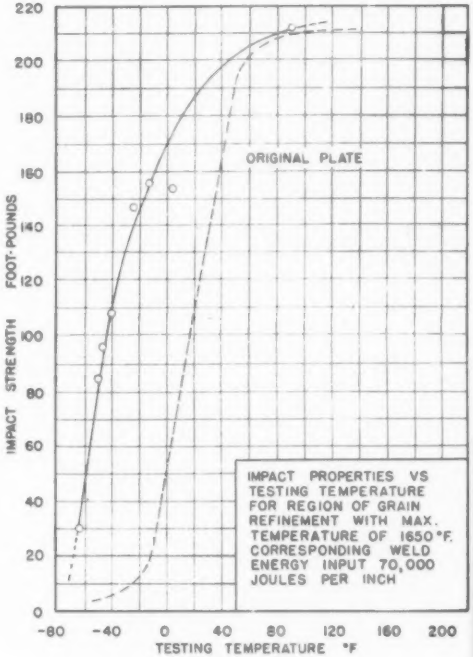
ORIGINAL PLATE
IMPACT PROPERTIES VS TESTING TEMPERATURE FOR REGION OF GRAIN REFINEMENT WITH MAX. TEMPERATURE OF 1650°F. CORRESPONDING WELD ENERGY INPUT 70,000 JOULES PER INCH
IMPACT STRENGTH FOOT-POUNDS
TESTING TEMPERATURE °F

Figure 10

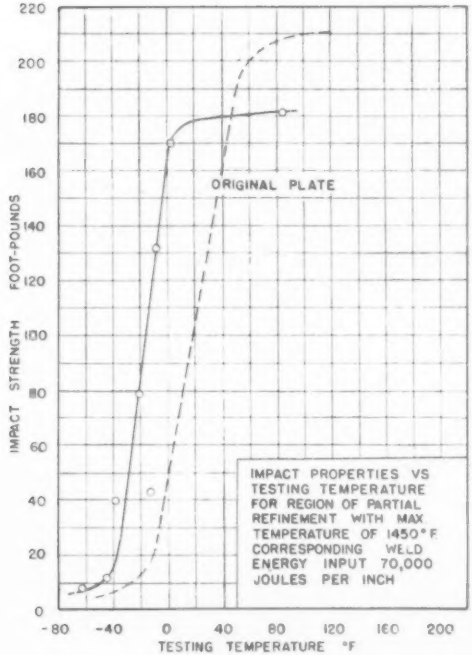
ORIGINAL PLATE
IMPACT PROPERTIES VS TESTING TEMPERATURE FOR REGION OF PARTIAL REFINEMENT WITH MAX TEMPERATURE OF 1450°F CORRESPONDING WELD ENERGY INPUT 70,000 JOULES PER INCH
IMPACT STRENGTH FOOT-POUNDS
TESTING TEMPERATURE °F

Figure 9

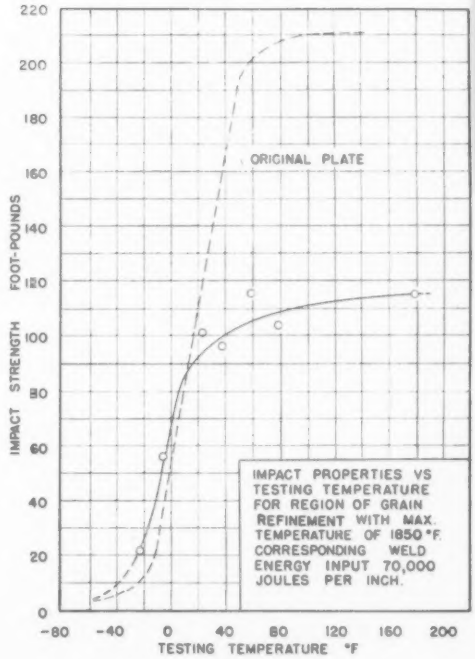
ORIGINAL PLATE
IMPACT PROPERTIES VS TESTING TEMPERATURE FOR REGION OF GRAIN REFINEMENT WITH MAX. TEMPERATURE OF 1850°F. CORRESPONDING WELD ENERGY INPUT 70,000 JOULES PER INCH.
IMPACT STRENGTH FOOT-POUNDS
TESTING TEMPERATURE °F

Figure 11

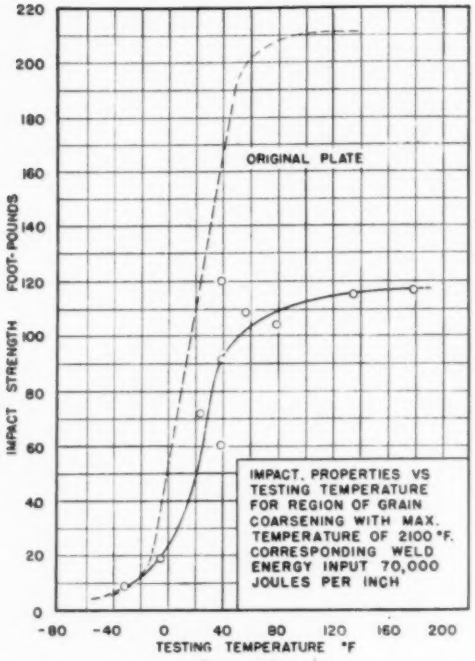
ORIGINAL PLATE
IMPACT, PROPERTIES VS TESTING TEMPERATURE FOR REGION OF GRAIN COARSENING WITH MAX. TEMPERATURE OF 2100 °F. CORRESPONDING WELD ENERGY INPUT 70,000 JOULES PER INCH
IMPACT STRENGTH FOOT-POUNDS
TESTING TEMPERATURE °F

Figure 12

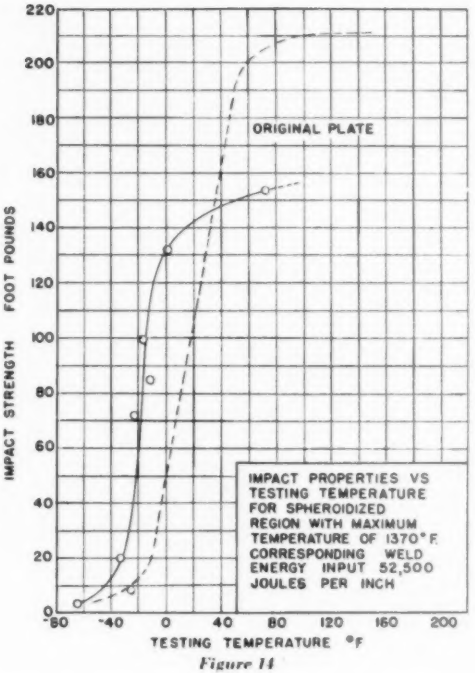
ORIGINAL PLATE
IMPACT PROPERTIES VS TESTING TEMPERATURE FOR SPHEROIDIZED REGION WITH MAXIMUM TEMPERATURE OF 1370 °F. CORRESPONDING WELD ENERGY INPUT 52,500 JOULES PER INCH
IMPACT STRENGTH FOOT POUNDS
TESTING TEMPERATURE °F

Figure 14

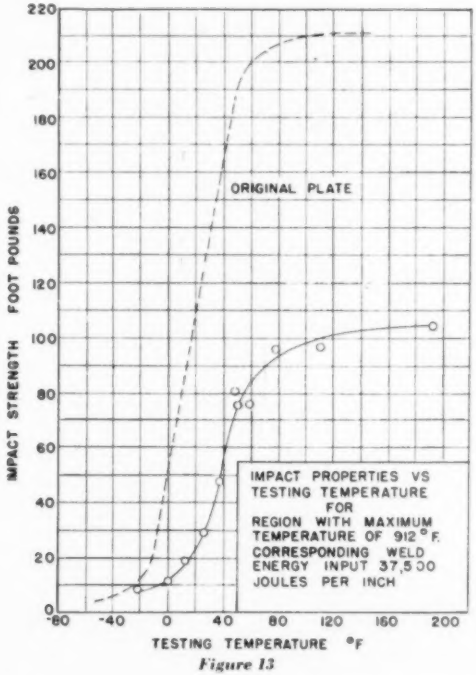
ORIGINAL PLATE
IMPACT PROPERTIES VS TESTING TEMPERATURE FOR REGION WITH MAXIMUM TEMPERATURE OF 912 °F. CORRESPONDING WELD ENERGY INPUT 37,500 JOULES PER INCH
IMPACT STRENGTH FOOT POUNDS
TESTING TEMPERATURE °F

Figure 13

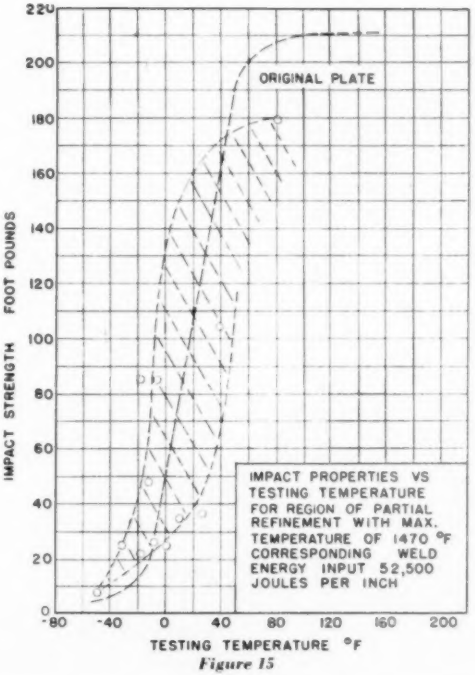
ORIGINAL PLATE
IMPACT PROPERTIES VS TESTING TEMPERATURE FOR REGION OF PARTIAL REFINEMENT WITH MAX. TEMPERATURE OF 1470 °F CORRESPONDING WELD ENERGY INPUT 52,500 JOULES PER INCH
IMPACT STRENGTH FOOT POUNDS
TESTING TEMPERATURE °F

Figure 15

Figures 16–26 show photographs at 1.5 × magnification of the fractures exhibited by series 1–11, respectively. The corresponding testing temperature is indicated above each figure. These fractures were employed to assist in the determination of the transition temperature, one criterion being the temperature producing a fracture half ductile and half brittle in nature.

Figure 27 is a summary curve, comparing the impact properties of all heat-affected structures associated with an energy input of 70,000 joules per inch, which were investigated. It will be noted that, of the microstructures investigated, the impact characteristics were the best for the region of refinement produced by a time-temperature cycle having a maximum temperature of 1650° F. (Series 6, Table 1, Appendix I). This was found true with regard to both the maximum value of impact strength and the transition temperature. This structure is found at a distance of 0.398 in. from the center line of an arc weld made in $\frac{1}{2}$-in. steel plate.

The results of the other tests included in Fig. 27 indicate that the impact properties deteriorate at either side of this point. Structures closer to the weld exhibit a rapid decrease in maximum value of impact

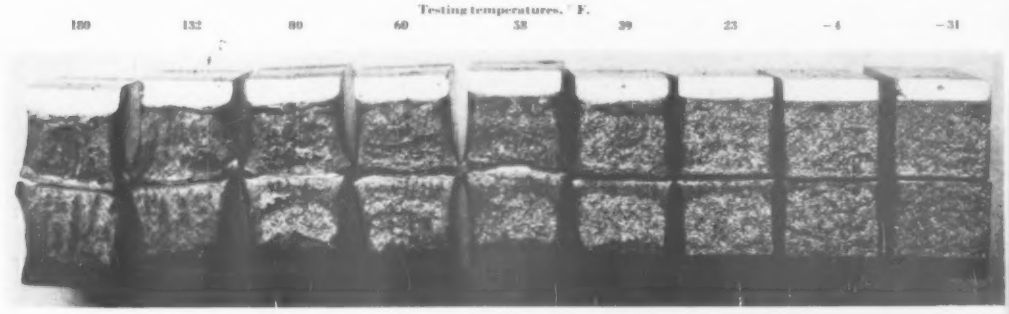

Fig. 16 Series 1—70,000 joules per inch: $T_{max.}$ = 700° F.; d = 0.935 in.

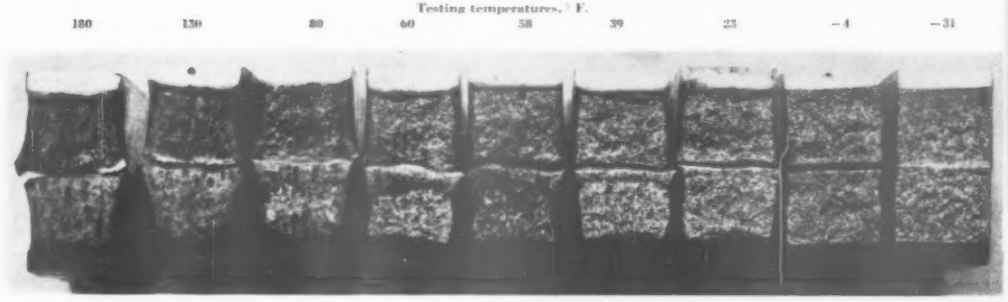

Fig. 17 Series 2—70,000 joules per inch: $T_{max.}$ = 950° F.; d = 0.625 in.

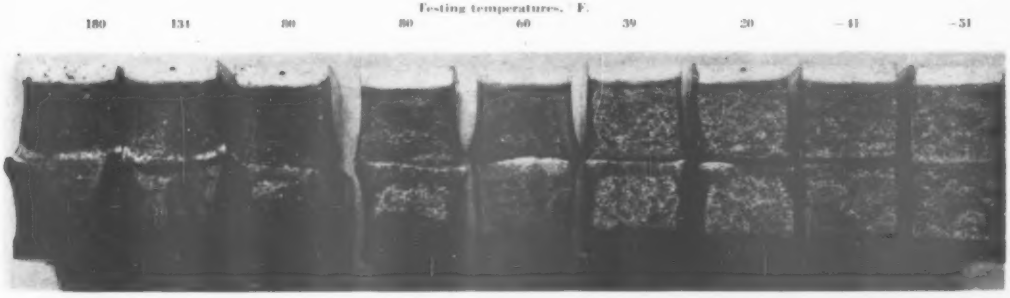

Fig. 18 Series 3—70,000 joules per inch: $T_{max.}$ = 1150° F.; d = 0.519 in.

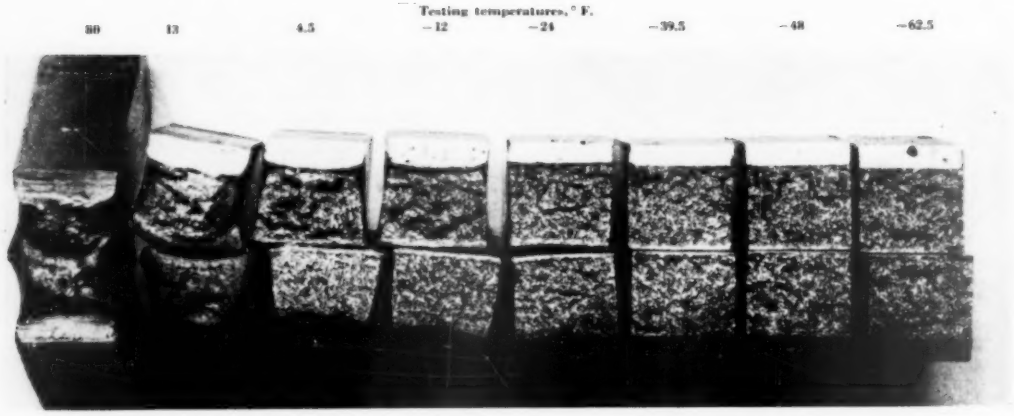

Fig. 19 Series 4—70,000 joules per inch; $T_{max.}$ = 1350° F.; d = 0.460 in.

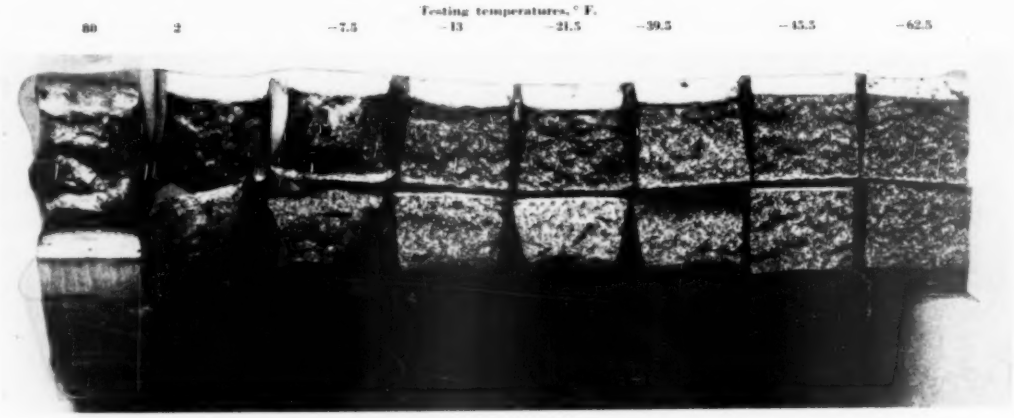

Fig. 20 Series 5—70,000 joules per inch; $T_{max.}$ = 1450° F.; d = 0.436 in.

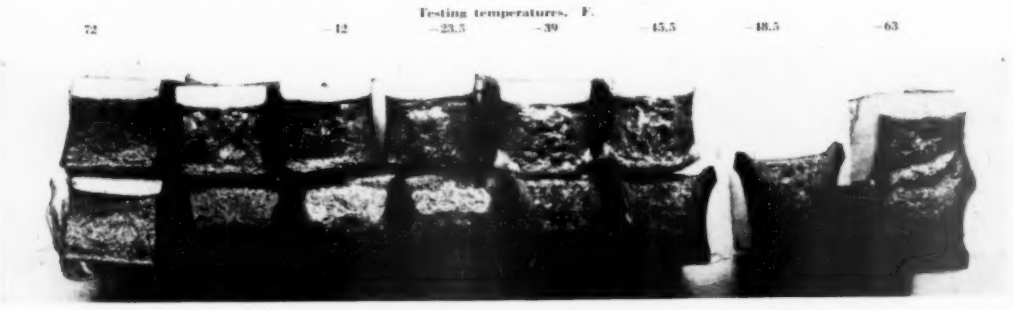

Fig. 21 Series 6—70,000 joules per inch; $T_{max.}$ = 1650° F.; d = 0.398 in.

strength, and also a rapid increase in transition temperature, over the region investigated. The structures found at greater distances from the weld center line also exhibit a decrease in impact properties. The poorest impact properties found were associated with the structure occurring 0.625 in. from the center line of an arc weld, and produced by a time-temperature cycle having a maximum of 950° F. As may be seen from Fig. 27 the maximum value of the impact strength was found to be approximately $^1/_2$ that found for the original plate, and the transition temperature was found to be located between 55 and 60° F. for this structure.

Figure 28 shows a comparison of the values of the temperature of transition from brittle to ductile fracture, determined by the slope and by the fracture methods for the microstructures tested, plotted as a function of the maximum temperature attained during production of the particular structure. Figure 29 presents the values of transition temperature determined by slope method, as a function of the distance from the center line of an arc weld made in $^1/_2$-in. plate, using an energy input of 70,000 joules per inch.

Similar deterioration of impact properties in the regions outside the normally considered heat-affected zone was observed in the case of the microstructure occurring at a distance of 0.400 in. from the center line of an arc weld made in $^1/_2$-in. plate, using an energy input of 37,500 joules per inch. This is shown in

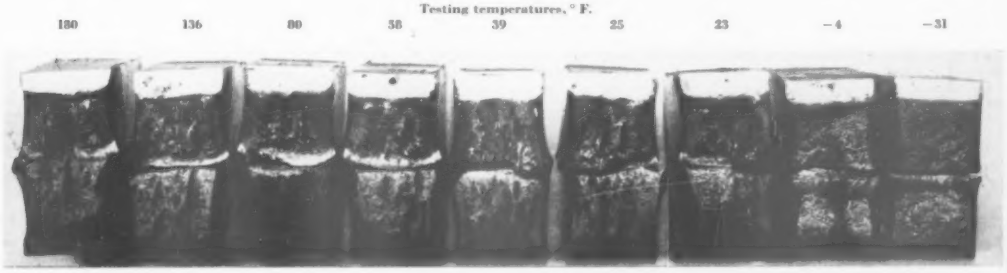

Fig. 22 Series 7—70,000 joules per inch; $T_{max.}$ = 1850° F.; d = 0.374 in.

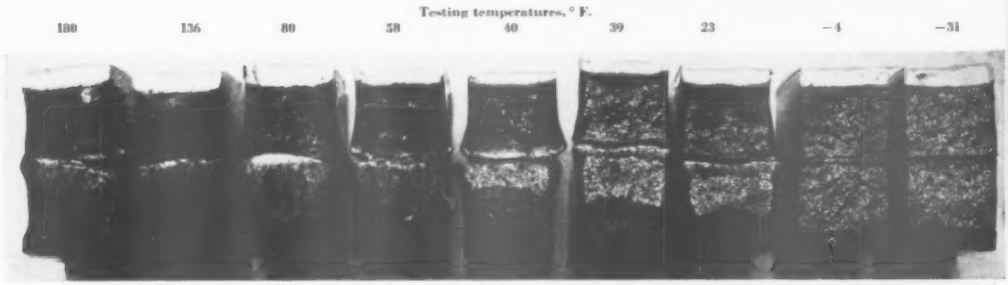

Fig. 23 Series 8—70,000 joules per inch; $T_{max.}$ = 2100° F.; d = 0.353 in.

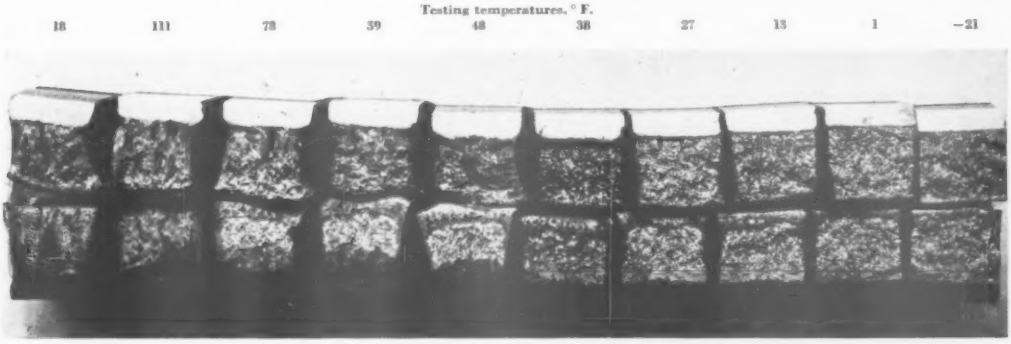

Fig. 24 Series 9—37,500 joules per inch; $T_{max.}$ = 912° F.; d = 0.400 in.

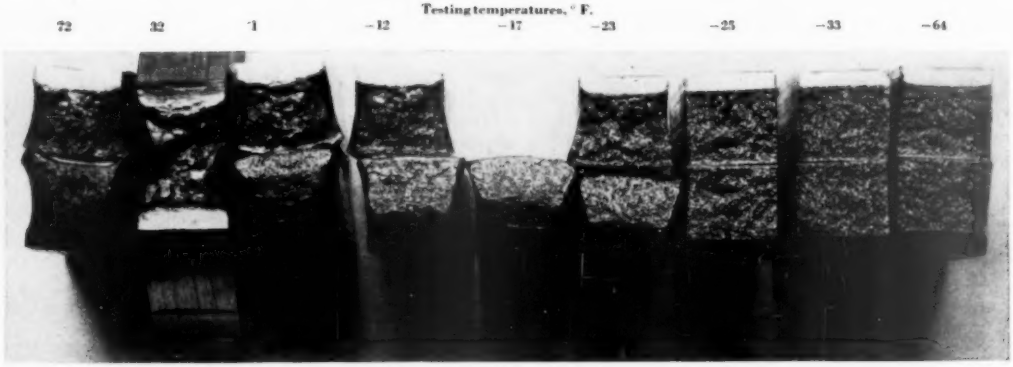

Fig. 25 Series 10—70,000 joules per inch; $T_{max.}$ = 1370° F.; d = 0.379 in.

Fig. 13. The maximum temperature attained in this region was also considerably below the A_1 transformation temperature, since the maximum temperature reached was 912° F.

Microstructures were obtained at 2000 × magnification of those structures tested which were associated with welds of 70,000 joules per inch energy input. Figures 30 through 35 permit comparison of the photomicrographs at this magnification of the structures produced in series 8, 7, 6, 5, 4 and 3, of maximum temperature 2100, 1850, 1650, 1450, 1350, and 1150° F., respectively.

The structure shown in Fig. 30 is typical of a structure produced by cooling a coarse-grained austenitic structure, and it is understandable that the impact properties of this structure should be correspondingly reduced. Figure 31 shows the internal structure produced in Series 7, and the grain size here does not differ appreciably from that produced in Series 6 (Fig. 32). The over-all decrease in the impact properties found in Series 7 (1850° F. maximum temperature), as compared to Series 6 (1650° F. maximum temperature), may be attributed to the coarser internal grain structure produced by the higher maximum tem-

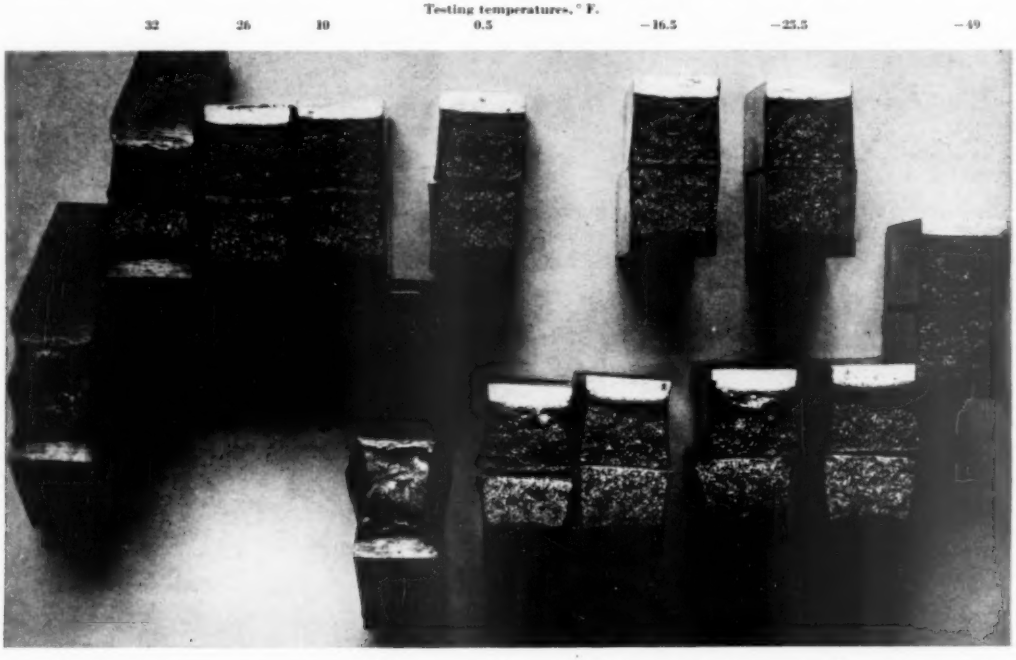

Fig. 26 Series 11—52,500 joules per inch; $T_{max.}$ = 1470° F.; d = 0.366 in.

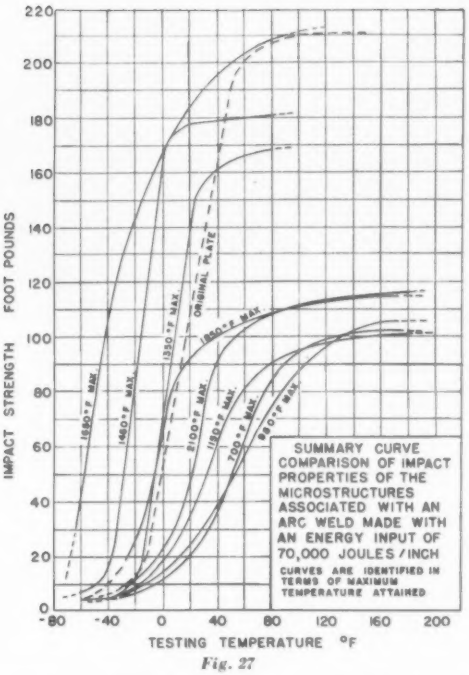
IMPACT STRENGTH FOOT POUNDS
TESTING TEMPERATURE °F
SUMMARY CURVE COMPARISON OF IMPACT PROPERTIES OF THE MICROSTRUCTURES ASSOCIATED WITH AN ARC WELD MADE WITH AN ENERGY INPUT OF 70,000 JOULES / INCH
CURVES ARE IDENTIFIED IN TERMS OF MAXIMUM TEMPERATURE ATTAINED
ORIGINAL PLATE
1650° F MAX.
1460° F MAX.
2100° F MAX.
1330° F MAX.
1850° F MAX.
1100° F MAX.
700° F MAX.
850° F MAX.

Fig. 27

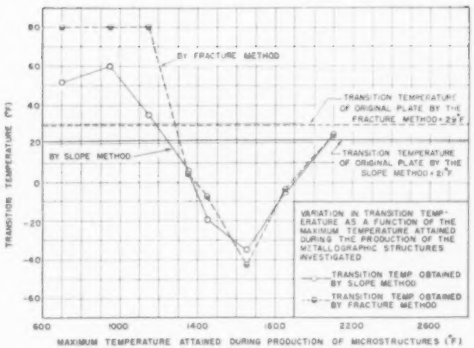
TRANSITION TEMPERATURE (°F)
BY FRACTURE METHOD
BY SLOPE METHOD
TRANSITION TEMPERATURE OF ORIGINAL PLATE BY THE FRACTURE METHOD = 25°F
TRANSITION TEMPERATURE OF ORIGINAL PLATE BY THE SLOPE METHOD = 21°F
VARIATION IN TRANSITION TEMPERATURE AS A FUNCTION OF THE MAXIMUM TEMPERATURE ATTAINED DURING THE PRODUCTION OF THE METALLOGRAPHIC STRUCTURES INVESTIGATED
TRANSITION TEMP OBTAINED BY SLOPE METHOD
TRANSITION TEMP OBTAINED BY FRACTURE METHOD
MAXIMUM TEMPERATURE ATTAINED DURING PRODUCTION OF MICROSTRUCTURES (°F)

Fig. 28

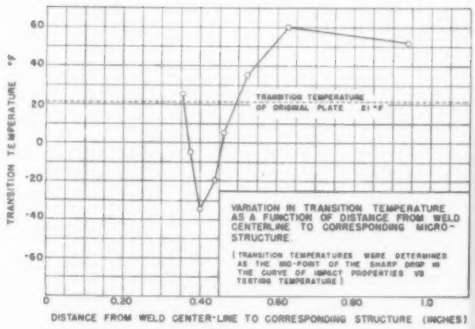
TRANSITION TEMPERATURE °F
TRANSITION TEMPERATURE OF ORIGINAL PLATE 21°F
VARIATION IN TRANSITION TEMPERATURE AS A FUNCTION OF DISTANCE FROM WELD CENTERLINE TO CORRESPONDING MICRO-STRUCTURE.
(TRANSITION TEMPERATURES WERE DETERMINED AS THE MID-POINT OF THE SHARP DROP ON THE CURVE OF IMPACT PROPERTIES VS TESTING TEMPERATURE)
DISTANCE FROM WELD CENTER-LINE TO CORRESPONDING STRUCTURE (INCHES)

Fig. 29

perature. This higher maximum temperature and associated faster cooling rate promoted the formation of a modified Widmannstatten structure, which caused the decrease in impact properties.

The structure of Series 5, shown in Fig. 33, being only partially refined, exhibits a slightly lower transition temperature than that of the original plate. This would appear to be in direct contradiction to the findings of investigators at Lehigh University.[4] These investigators, by tests of specimens heat treated to approximate the weld heat-affected structures, indicated that the region of partial refinement exhibited the poorest impact properties to be found in the heat-affected zone.

The spheroidized structure of Series 4 shown in Fig. 34 shows little significant change in impact properties. Although Nippes and Savage[5] previously reported low-impact properties, from attempts at direct testing of this structure in welded specimens, it is now established that the original work erred by an oversight, as will be pointed out below.

Fig. 30 Microstructure associated with a point 0.353 in. from the center line of an arc weld made with an energy input of 70,000 joules per inch, as made by duplication of the actual heating and cooling cycle. Maximum temperature, 2100° F. 2000 ×

Fig. 31 Microstructure associated with a point 0.374 in. from the center line of an arc weld made with an energy input of 70,000 joules per inch, as made by duplication of the actual heating and cooling cycle. Maximum temperature, 1850° F. 2000 ×

Fig. 32 Microstructure associated with a point 0.398 in. from the center-line of an arc weld made with an energy input of 70,000 joules per inch, as made by duplication of the actual heating and cooling cycle. Maximum temperature, 1650° F. 2000 ×

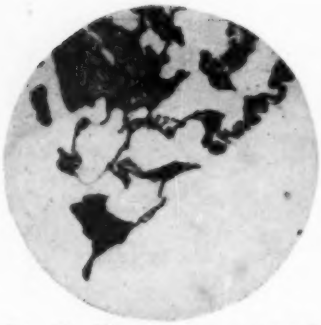

Fig. 33 Microstructure associated with a point 0.436 in. from the center line of an arc weld made with an energy input of 70,000 joules per inch, as made by duplication of the actual heating and cooling cycle. Maximum temperature, 1450° F. 2000 ×

Fig. 34 Microstructure associated with a point 0.460 in. from the center-line of an arc weld made with an energy input of 70,000 joules per inch, as made by duplication of the actual heating and cooling cycle. Maximum temperature, 1350° F. 2000 ×

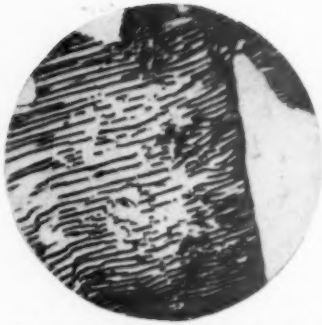

Fig. 35 Microstructure found beyond 0.470 in. from center line of an arc weld made with an energy input of 70,000 joules per inch, as made by duplication of the actual heating and cooling cycle. Maximum temperature below effective A_1 transformation temperature. 2000 ×

Figure 35 shows a photomicrograph of Series 3 at 2000 ×. This was chosen as representative of the structures found in regions where the A_1 transformation temperature was not exceeded. Furthermore no significant difference was observed between this structure and that of the original plate material at 2000 × magnification.

Figures 5, 6, and 7 show the impact properties of the structures produced by time-temperature cycles with maximum temperatures of 700, 950 and 1150° F., respectively. All three structures are characterized by values of maximum impact strength, approximately one-half that of the original plate, and transition temperatures ranging from 20 to 30° F. higher than those of the original plate. This information may be found summarized in Fig. 27. Figures 28 and 29 show the trend of transition temperature as a function of the maximum temperature attained in the time-temperature cycle which produces the structures, and the distance of the corresponding structure from the weld center line, respectively.

According to Jungbluth,[6] aging phenomena in low-carbon steels are characterized by a general reduction of the impact strength, and an increase in the value of the transition temperature. The fact that these trends were observed in this region, and that the range of temperature attained was in all cases considerably below the effective A_1 tranformation temperature, suggests that the phenomena observed in series 1, 2 and 3 must be attributed to an aging reaction. Two general types of aging phenomena are common in low-carbon steels:

1. Carbon or quench-aging.
2. Strain-aging.

In view of the short interval of time between making of the specimens and testing (24 hr. in most cases) and the low maximum temperatures attained by the time-temperature cycle experienced by these specimens, it seems unlikely that carbon or quench-aging is the major contributor to the observed properties. This is believed true, as higher soaking temperatures followed by relatively long times at slightly elevated temperature are usually required to promote carbon or quench aging.

The general reduction of the impact properties and increase in the value of the transition temperature are therefore attributed largely to strain-aging. Certainly, the requisites for strain-aging are present, since strains are imposed on the specimen due to restriction of thermal expansion and contraction during treatment.

The method here employed permits obtaining significant tests of the individual microstructures produced near an electric arc weld by duplication of the desired structure in suitable test specimens. Since the zone of uniform structure was perpendicular to the axis of the specimen, no problems of integrated test results were encountered. In a previous paper,[5] the authors were actually testing a portion of the region next to the spheroidized region, inadvertently, due to the sloping nature of the heat-affected zones. The impact failure, though probably initiated in the spheroidized region, was known to traverse a portion of the apparently unaffected plate material. Since this plate material is now known to be subject to a deleterious aging process the previously obtained low-impact test results are understandable. The presence of this structure not having been confirmed at that time, the investigators overlooked the possibility of its existence.

Figure 13 shows the impact properties as a function of testing temperature for the microstructure associated with a point of 0.400 in. from the center line of an arc weld with 37,500 joules per inch. The maximum temperature attained in the production of this structure was also below the effective A_1 transformation temperature (being only 912° F.). This structure was found to confirm the presence of an aging phenomenon in this region.

Figures 14 and 15 show the impact properties of a spheroidized and a partially refined structure, respectively, associated with an arc weld made in $^1/_2$-in. plate, using an energy input of 52,500 joules per inch (series 10 and 11, respectively). While the spheroidized structure shows a somewhat superior transition temperature as compared to the original plate, the partially refined structure shows a wide spread of values in the transition region. The reason for this anomalous behavior is not well understood, and will no doubt be the subject of further research.

CONCLUSIONS

1. Metallographic examination of specimens heat treated by means of the time-temperature control device revealed no detectable variation in microstructure over the cross section of the specimen. In addition, with the 0.70-in. clamping distance employed, a region of approximately 0.10 in. on either side of the control thermocouple location exhibited similar uniformity in a longitudinal direction. It is to be understood, however, that a reduction in the free length of the specimen, as clamped in the jaws of the flash welder, will reduce the breadth of this region of metallographic uniformity.

2. The validity of the method of duplication of the metallographic structures by means of the time-temperature control device previously described was established.

3. It was found possible to obtain test specimens by the above method in sufficient number to obtain a significant test of several of the microstructures in the heat-affected zones of arc welds.

4. A systematic survey was made of the impact properties of the various microstructures in the neighborhood of an arc weld made in $^1/_2$-in. plate with an energy input of 70,000 joules per inch.

5. This survey revealed that the coarsened region next to the weld exhibited increasingly poor impact properties the higher the maximum temperature attained. Although limitations in the present design of the control restricted the investigation of those structures 0.353 in. from the weld center line, and beyond, the trend observed is expected to continue, as refinements in the existing control permit investigation of the coarser structures nearer the weld center line. Since the fusion line, with an energy input of 70,000 joules per inch, occurs at a distance of approximately 0.33 in. from the center line, much coarser structures are yet to be investigated.

6. The region of refinement exhibited various impact properties depending on the position in the region considered. The internal structure of the grains in this region, as well as the grain size, was found to have an effect.

7. A region farther removed from the weld than the normally considered heat-affected zone showed the poorest impact properties of any of the structures tested.

8. Since the maximum temperatures attained in this region were always considerably below the effective A_1 transformation temperature, the decrease in impact properties was attributed to an aging phenomenon.

9. The combination of conditions seems to indicate this aging phenomenon to be one of strain-aging.

10. The maximum impact strength in this region was found to be about one-half that of the original plate material, and the transition temperature 20 to 50° F. higher, depending on criteria used in determination of transition temperature.

11. The partially refined and spheroidized structures were found to have impact properties intermediate in value between those of the tough, fine-grained structure and aged material farther out in the plate.

SUGGESTIONS FOR FURTHER RESEARCH

Practically limitless possibilities for further research, both in welding and metallurgical fields, are made possible by the time-temperature control device. Among those appearing most promising are:

1. Further investigation of the heat-affected zones of arc welds to determine the effect of energy-input, preheat, etc., on the transition phenomena of the heat-affected structures. It should be possible to construct cams for the duplication of almost any of the structures produced in the heat-affected zone of an arc weld. Possible modificatior of the cam-operated potentiometer such as was discussed previously,[2] would undoubtedly extend the useful range of application of the equipment.

2. Investigation of short-time, high-temperature graphitization problems encountered with molybdenum bearing steels should also prove a fruitful field for further research.

3. Investigation of the sensitizing effect produced by the welding of stainless steels. Problems of grain-boundary corrosion, promoted by welding methods of fabrication, could perhaps be investigated using the time-temperature controller.

4. Extension of present information on rates of austenization and other short-time-temperature relationships for steels should also be possible.

5. Investigation of tempering effects in alloy steels when exposed to high temperatures for short periods of time should also prove interesting.

6. In short almost any metallurgical phenomenon involving short time reactions might well be investigated using this type of equipment.

ACKNOWLEDGMENT

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Appendix I

CALCULATIONS FOR DETERMINATION OF TIME-TEMPERATURE CYCLES AND ASSOCIATED CAMS

The calculation of the necessary time-temperature cycles, and other information necessary for the production of cams for the duplication of the heat-affected zones of an arc weld:

The method of calculation will be briefly outlined below. A time-temperature cycle will be calculated

Table 1—Calculations Required for the Production of a Cam for the Duplication of a Microstructure Found near an Electric Arc Weld

Corresponding weld energy input, joules per inch	70,000
Initial plate temperature (T_0), ° F	72
Maximum temperature attained ($T_{max.}$), ° F	700
Calculated distance of structure from weld center line (d), in.	0.935
Time to reach maximum ($t_{max.}$), sec	46.7

Time, sec.	$F(s, d)$	*T*, ° F.	*T, mv.*	T, in. (*in. @ 4 mv./in.*)
2	0.57	112	0.77	0.19
3	1.20	156	1.77	0.443
4	1.81	199	2.77	0.697
5	2.26	230	3.50	0.875
6	2.80	268	4.35	1.09
7.5	3.55	320	5.50	1.38
10	4.70	401	7.32	1.83
15	6.53	529	10.20	2.55
20	7.67	616	12.20	3.05
30	8.67	686	13.83	3.46
40	8.95	698	14.10	3.52
46.7	8.97	700	14.15	3.54
60	8.70	680	13.7	3.42
80	7.89	630	12.53	3.14
100	7.30	583	11.42	2.86
120	6.83	550	10.67	2.67
150	6.35	516	9.9	2.48
180	6.05	495	9.43	2.36

Table 2—Calculations Required for the Production of a Cam for the Duplication of a Microstructure Found near an Electric Cam Weld

Corresponding weld energy input, joules per inch	70,000
Initial plate temperature (T_0), ° F	72
Maximum temperature attained ($T_{max.}$), ° F	950
Calculated distance of structure from weld center line (d), in.	0.625
Time to reach maximum ($t_{max.}$), sec	20.3

Time, sec.	$F(s, d)$	*T*, ° F.	*T, mv.*	*T*, in. (*in. @ 4 mv./in.*)
2	3.85	341	5.98	1.50
3	5.70	471	8.88	2.22
4	7.17	574	11.23	2.805
5	8.50	667	13.38	3.34
6	9.50	737	15.03	3.755
7.5	10.40	801	16.53	4.13
10	11.20	857	17.84	4.46
15	12.13	922	19.38	4.84
20	12.53	948	19.85	4.97
20.3	12.55	950	20.05	5.01
30	12.23	928	19.53	4.88
40	11.65	888	18.57	4.64
60	10.38	798	16.45	4.11
80	9.20	716	14.53	3.63
100	8.47	664	13.32	3.33
120	7.83	620	12.30	3.07
150	7.08	567	11.07	2.76
180	6.55	530	10.23	2.56

Table 3—Calculations Required for the Production of a Cam for the Duplication of a Microstructure Found near an Electric Cam Weld

Corresponding weld energy input, joules per inch	70,000
Initial plate temperature (T_0), ° F	72
Maximum temperature attained ($T_{max.}$), ° F	1150
Calculated distance of structure from weld center line (d), in.	0.5192
Time to reach maximum ($t_{max.}$), sec	11.81

Time, sec.	$F(s, d)$	*T*, ° F.	*T, mv.*	*T, in.* (*in. @ 4 mv./in.*)
2	6.58	533	10.3	2.58
3	8.70	681	13.72	3.435
4	10.60	814	16.83	4.21
5	12.60	954	20.14	5.03
6	13.7	1031	21.97	5.49
7.5	14.87	1112	23.87	5.97
10	15.33	1144	24.64	6.16
11.81	15.39	1150	24.78	6.19
15	15.33	1144	24.64	6.16
20	14.95	1118	24.03	6.01
30	13.88	1042	22.23	5.56
40	12.93	978	20.7	5.17
60	11.22	860	17.9	4.48
80	9.88	764	15.65	3.91
100	9.04	705	14.27	3.56
120	8.28	652	13.04	3.26
150	7.50	597	11.77	2.94
180	6.92	557	10.84	2.71

Table 4—Calculations Required for the Production of a Cam for the Duplication of a Microstructure Found near an Electric Cam Weld

Corresponding weld energy input, joules per inch	70,000
Initial plate temperature (T_0), ° F	72
Maximum temperature attained ($T_{max.}$), ° F	1350
Calculated distance of structure from weld center line (d), in.	0.460
Time to reach maximum ($t_{max.}$), sec	8.57

Time, sec.	$F(s, d)$	*T*, ° F.	*T, mv.*	*T, in.* (*in. @ 4 mv./in.*)
2	8.9	694.5	14.02	3.505
3	11.9	906	19.0	4.75
4	14.36	1078	23.10	5.77
5	16.15	1203	26.02	6.505
6	17.22	1278	27.80	6.95
7.5	18.18	1344	29.32	7.33
8.57	18.24	1350	29.48	7.37
10	18.07	1338	29.20	7.30
15	17.30	1283	27.90	6.975
20	16.45	1223	26.50	6.625
30	14.94	1118	24.02	6.005
40	13.71	1033	22.02	5.505
60	11.76	895	18.74	4.68
80	10.30	794	16.36	4.09
100	9.39	728	14.80	3.70
120	8.59	673	13.52	3.38
150	7.76	615	12.17	3.04
180	7.13	570	11.14	2.78

for a point in the neighborhood of an arc weld in $^1/_2$-in. plate, made with an energy input of 70,000 joules per inch. The point used for illustration will be one experiencing a maximum temperature of 1650° F., when an original plate temperature of 72° F. is employed.

Calculations

Maximum temperature attained, $T_{max.}$, ° F..... 1650
Original plate temperature, T_0, ° F..... 72

1. Determine the value of the distance (d) from the weld center line to the desired point as follows:

(a) Using the general equation

$$T - T_0 = \frac{F(s, d)}{1000} \times \text{Energy Input} \times \text{Input Factor} \quad (1)$$

where $T - T_0 = 1650 - 72 = 1578°$ F.; energy input = 70,000 joules per inch; and input factor = 1.0, the value of the $F(s, d)$ max. may be found to be $F(s, d)$ max. = 22.55.

(b) From Fig. 4 of Reference 1* determine the corresponding distance to be $d = 0.398$ in. from the weld center line.

* All values of $F(s, d)$, Input Factor, etc., necessary for these calculations will be found in a previously published paper, Reference 1.

Table 5—Calculations Required for the Production of a Cam for the Duplication of a Microstructure Found near an Electric Cam Weld

Corresponding weld energy input, joules per inch..... 70,000
Initial plate temperature (T_0), ° F..... 72
Maximum temperature attained ($T_{max.}$), ° F..... 1450
Calculated distance of structure from weld center line (d), in..... 0.436
Time to reach maximum ($t_{max.}$), sec..... 7.75

Time, sec.	$F(s, d)$	T, ° F.	T, *mv.*	T, *in. (in. @ 4 mv./in.)*
2	10.23	788	16.23	4.075
3	13.50	1017	21.63	5.408
4	16.1	1200	25.95	6.47
5	18.05	1335	29.13	7.28
6	19.06	1407	30.80	7.70
7.5	19.65	1450−	31.77	7.94
7.75	19.66	1450	31.78	7.94
10	19.32	1425	31.20	7.80
15	18.20	1347	29.40	7.35
20	17.06	1265	27.47	6.88
30	15.37	1147	24.70	6.17
40	14.04	1055	22.52	5.64
60	12.0	913	19.18	4.795
80	10.49	806	16.66	4.16
100	9.54	739	15.08	3.77
120	8.72	682	13.74	3.435
150	7.87	623	12.36	3.09
180	7.22	577	11.30	2.825

Table 6—Calculations Required for the Production of a Cam for the Duplication of a Microstructure Found near an Electric Cam Weld

Corresponding weld energy input, joules per inch..... 70,000
Initial plate temperature (T_0), ° F..... 72
Maximum temperature attained ($T_{max.}$), ° F..... 1650
Calculated distance of structure from weld center line (d), in..... 0.398
Time to reach maximum ($t_{max.}$), sec..... 6.55

Time, sec.	$F(s, d)$	T, ° F.	T, *mv.*	T, *in. (in. @ 5 mv./in.)*
2	13.1	978	20.7	4.34
3	17.2	1276	27.75	5.55
4	20.2	1486	32.6	6.52
5	21.9	1604	35.28	7.06
6	22.5	1646	36.23	7.25
6.55	22.55	1650	36.3	7.26
7.5	22.3	1632	35.9	7.18
10	21.35	1564	34.38	6.87
15	19.55	1440	31.55	6.31
20	18.1	1340	29.25	5.85
30	16.08	1196	25.85	5.17
40	14.57	1092	23.4	4.68
60	12.37	937	19.75	3.95
80	10.80	828	17.15	3.43
100	9.77	756	15.48	3.095
120	8.95	698	14.10	2.82
150	8.05	635	12.65	2.53
180	7.35	586	11.50	2.30

Table 7—Calculations Required for the Production of a Cam for the Duplication of a Microstructure Found near an Electric Cam Weld

Corresponding weld energy input, joules per inch..... 70,000
Initial plate temperature (T_0), ° F..... 72
Maximum temperature attained ($T_{max.}$), ° F..... 1850
Calculated distance of structure from weld center line (d), in..... 0.3738
Time to reach maximum ($t_{max.}$), sec..... 5.61

Time, sec.	$F(s, d)$	T, ° F.	T, *mv.*	T, *in. (in. @ 8 mv./in.)*
2	15.80	1280	27.84	3.48
3	21.0	1542	33.88	4.23
4	24.24	1771	38.96	4.77
5	25.20	1838	40.42	5.05
5.61	25.40	1850	40.68	5.08
6	25.16	1833	40.32	5.04
7.5	24.23	1771	38.96	4.87
10	22.78	1597	35.10	4.39
15	20.40	1501	32.97	4.12
20	18.72	1383	30.24	3.805
30	16.51	1230	26.66	3.333
40	14.89	1114	23.93	3.00
60	12.61	955	20.16	2.52
80	10.98	840	17.45	2.18
100	9.91	766	15.7	1.962
120	9.08	707	14.33	1.790
150	8.18	644	12.85	1.607
180	7.43	592	11.65	1.455

Table 8—Calculations Required for the Production of a Cam for the Duplication of a Microstructure Found near an Electric Cam Weld

Corresponding weld energy input, joules per inch..... 70,000
Initial plate temperature (T_0), ° F..... 72
Maximum temperature attained ($T_{max.}$), ° F..... 2100
Calculated distance of structure from weld center line (d), in..... 0.3534
Time to reach maximum ($t_{max.}$), sec..... 4.80

Time, sec.	$F(s, d)$	T, ° F.	T, *mv.*	T, *in. (in. @ 8 mv./in.*
2	19.0	1402	30.67	3.835
3	25.60	1863	39.96	4.99
4	28.51	2067	45.26	5.66
4.80	28.98	2100	45.95	5.75
5	28.68	2082	45.58	5.70
6	27.81	2020	44.28	5.53
7.5	26.16	1902	41.80	5.23
10	24.05	1756	38.64	4.83
15	21.12	1551	34.08	4.26
20	19.23	1420	31.10	3.885
30	16.88	1253	27.20	3.40
40	15.15	1132	24.35	2.92
60	12.80	968	20.47	2.56
80	11.13	852	17.72	2.215
100	10.03	775	15.92	1.99
120	9.18	724	14.72	1.84
150	8.26	650	13.0	1.625
180	7.50	597	11.76	1.47

2. Determine the time (s) required to attain the maximum value of the function from Fig. 2 of Reference 1 to be $s = 6.55$ sec.

3. By means of Figs. 5–7, Reference 1 (these show the values of $F(s,d)$ as a function of distance for values of time 2, 3, 4, 5, 6, 7.5, 10, 15, 20, 30, 40, 60, 80, 100, 120, 150 and 180 sec.), determine the values of the function $F(s, d)$ in Equation 1 at distance of 0.398 in. from the weld center line.

These values of $F(s, d)$ are shown opposite the corresponding values of time in Table 6.

4. Substitute these values of $F(s,d)$ in Equation 1 and solve for T, the temperature at a point 0.398 in. from weld center line at the indicated time. These values of T are shown in Column 3 of Table 6.

5. By means of an appropriate temperature-millivolt conversion table for the chromel-alumel thermocouple used, obtain corresponding values of required reference voltage as a function of time, shown in Column 4 of Table 6.

6. Divide the values of the reference voltage in millivolts by the calibration factor for the cam-operated slide wire, in this case 4 mv./in. The resulting values represent inches displacement from the cold junction reference line on the cam, and are shown in Column 5 of Table 6.

7. Lay out the cam[2] using a time scale of 5 in. per minute, and plotting the displacements in Column 5 of Table 6 as a function of time.

Table 9—Calculations Required for the Production of a Cam for the Duplication of a Microstructure Found near an Electric Cam Weld

Corresponding weld energy input, joules per inch	37,500
Initial plate temperature (T_0), ° F	72
Maximum temperature attained ($T_{max.}$), ° F	912
Calculated distance of structure from weld center line (d), in.	0.400
Time to reach maximum ($t_{max.}$), sec.	6.55

Time, sec.	$F(s, d)$	T, ° F.	T, *mv.*	T, *in. (in. @ 4 mv./in.)*
2	12.90	556	10.83	2.71
3	16.85	704	14.25	3.56
4	20.00	822	17.02	4.26
5	21.64	884	18.48	4.62
6	22.32	908	19.05	4.76
6.55	22.4	912	19.15	4.79
7.5	22.18	902	18.9	4.73
10.0	21.24–	868	18.1	4.525
15	19.50	803	16.58	4.14
20	18.05	749	15.3	3.825
30	16.05	674	13.55	3.385
40	14.55	617	12.23	3.06
60	12.35	535	10.34	2.59
80	10.78	476	9.0	2.25
100	9.75	440	8.18	2.045
120	8.94	409	7.48	1.87
150	8.05	376	6.76	1.69
180	7.35	350	6.18	1.545

Table 10—Calculations Required for the Production of a Cam for the Duplication of a Microstructure Found near an Electric Cam Weld

Corresponding weld energy input, joules per inch	52,500
Initial plate temperature (T_0), ° F	72
Maximum temperature attained ($T_{max.}$), ° F	1370
Calculated distance of structure from weld center line (d), in.	0.379
Time to reach maximum ($t_{max.}$), sec.	5.80

Time, sec.	$F(s, d)$	T, ° F.	T, *mv.*	T, *in. (in. @ 4 mv./in.)*
2	15.1	866	18.05	4.51
3	20.0	1123	24.15	6.04
4	23.25	1294	28.18	7.045
5	24.4	1354	29.56	7.39
5.8	24.70	1370	29.94	7.44
6	24.54	1361	29.92	7.43
7.5	23.78	1320	28.78	7.195
10	22.45	1252	27.18	6.795
15	20.21	1134	24.40	6.10
20	18.60	1049	22.38	5.595
30	16.40	934	19.68	4.92
40	14.81	850	17.68	4.42
60	12.55	731	14.88	3.72
80	10.94	647	12.92	3.23
100	9.87	590	11.60	2.90
120	9.05	547	10.60	2.65
150	8.15	500	9.54	2.38
180	7.42	461	8.68	2.17

Table 11—Calculations Required for the Production of a Cam for the Duplication of a Microstructure Found near an Electric Cam Weld

Corresponding weld energy input, joules per inch	52,500
Initial plate temperature (T_0), ° F	72
Maximum temperature attained ($T_{max.}$), ° F	1470
Calculated distance of structure from weld center line (d), in.	0.366
Time to reach maximum ($t_{max.}$), sec.	5.30

Time, sec.	$F(s, d)$	T, ° F.	T, *mv.*	T, *in. (in. @ 4 mv./in.)*
2	16.92	962	20.23	5.08
3	22.60	1260	27.38	6.845
4	25.75	1423	31.18	7.795
5	26.45	1462	32.05	8.01
5.30	26.61	1470	32.24	8.06
6	26.12	1444	31.64	7.91
7.5	24.93	1381	30.20	7.55
10	23.28	1294	28.18	7.04
15	20.69	1160	25.03	6.26
20	18.92	1066	22.80	5.52
30	16.65	947	19.98	4.995
40	14.99	859	17.88	4.47
60	12.68	738	15.05	3.76
80	11.04	652	13.04	3.26
100	9.95	594	11.70	2.925
120	9.11	550	10.68	2.67
150	8.20	503	9.60	2.40
180	7.46	464	8.73	2.18

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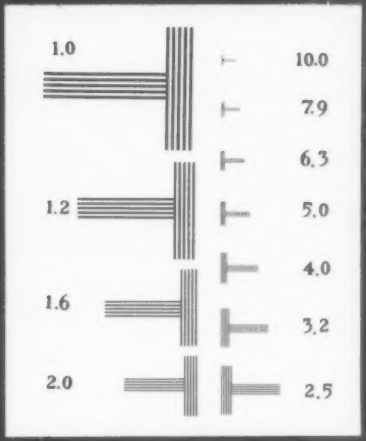

100 MILLIMETERS

INSTRUCTIONS Resolution is expressed in terms of the lines per millimeter recorded by a particular film under specified conditions. Numerals in chart indicate the number of lines per millimeter in adjacent "T-shaped" groupings.

In microfilming, it is necessary to determine the reduction ratio and multiply the number of lines in the chart by this value to find the number of lines recorded by the film. As an aid in determining the reduction ratio, the line above is 100 millimeters in length. Measuring this line in the film image and dividing the length into 100 gives the reduction ratio. Example: the line is 20 mm. long in the film image, and 100 / 20 = 5.

Examine "T-shaped" line groupings in the film with microscope, and note the number adjacent to finest lines recorded sharply and distinctly. Multiply this number by the reduction factor to obtain resolving power in lines per millimeter. Example: 7.9 group of lines is clearly recorded while lines in the 10.0 group are not distinctly separated. Reduction ratio is 5, and 7.9 x 5 = 39.5 lines per millimeter recorded satisfactorily. 10.0 x 5 = 50 lines per millimeter which are not recorded satisfactorily. Under the particular conditions, maximum resolution is between 39.5 and 50 lines per millimeter.

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